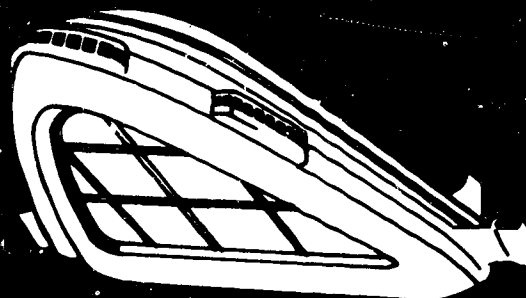


(NASA-CR-137799) AN ASSESSMENT OF LIGHTER  
THAN AIR TECHNOLOGY Final Report  
(Massachusetts Inst. of Tech.) 84 p HC  
\$5.00 CSCL 01B



# AN ASSESSMENT of LIGHTER THAN AIR TECHNOLOGY



Joseph F. Vittek, Jr.

FTL Report R75-1  
June, 1975

Sponsored by NASA-NAVY-DOT-FAA

FLIGHT TRANSPORTATION LABORATORY

N76-15014

Unclas

G3/01 J7859

# **AN ASSESSMENT OF LIGHTER THAN AIR TECHNOLOGY**

**FINAL REPORT OF THE  
INTERAGENCY WORKSHOP ON  
LIGHTER THAN AIR VEHICLES**

---

**M.I.T. FLIGHT TRANSPORTATION LABORATORY**

**FTL REPORT R75-1  
June, 1975**

**Edited by  
Joseph F. Vittek, Jr.**

This report was prepared under joint NASA / Navy / DOT / FAA Grant No. NSG-2024. The views expressed herein are not necessarily the official opinions of the sponsoring agencies. The Systems Study Division, NASA Ames Research Center, Naval Air Development Center, U.S. Navy Office of Aviation Policy, FAA, and Office of the Assistant Secretary for Systems Development and Technology, DOT.

Portions of this report may be quoted without permission when credited.

**FLIGHT TRANSPORTATION LABORATORY  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
CAMBRIDGE, MASSACHUSETTS 02139**

---

## CHAIRMAN'S MESSAGE

---

On behalf of the sponsoring agencies, NASA, Navy, DOT and FAA, I extend our thanks to all those who contributed to a successful LTA Workshop at Monterey, California, in September, 1974. Well beyond our expectations, the magnitude and breadth of representation was gratifying. Our purpose for sponsoring the workshop was to provide a timely forum for the exposition and discussion of current views, ideas, and activities on all aspects of LTA. With no intent to develop an advocacy position, either for or against LTA, we wanted to objectively survey those facts and speculations which abound amid the recent revival of interest. This we accomplished, and more. Through the confluence of opinions, prejudices, and ideas, often diverse but always in the spirit of camaraderie, this intense week focusing on LTA established a watershed from which future activities will flow. And, indeed, much work lies ahead. If the full potential of LTA is to be realized, it will require the collective efforts of industry, government and the universities. To assist in this effort, the Workshop Report and Proceedings provide an extension of a memorable week in Monterey.

*Alfred C. Mascy  
General Chairman  
NASA Ames Research Center*

## **TABLE OF CONTENTS**

<b>Chairman's Message</b> .....	iii
<b>Introduction</b>	
The Workshop Concept .....	2
The Workshop on Lighter Than Air Vehicles .....	3
<b>History and Background</b>	
Early Flight .....	4
Zeppelin and His Airships .....	5
Airships at War .....	6
The Golden Age—The Period Between the Wars .....	8
Airships in the United States .....	11
The End of an Era .....	15
Blimps at War .....	16
The Decade 1964-1974 .....	17
<b>The Workshop Report</b>	
Policy Working Group .....	18
Workshop Policy Statement .....	21
Market Analysis Working Group .....	23
Economics Working Group .....	36
Operations Working Group .....	39
Technology Working Group .....	49
<b>Comments</b>	
Changes in Text .....	69
General Comments .....	71
Comments on the Policy Working Group Report .....	74
Comment on the Economics Working Group Report .....	75
Comment on the Operations Working Group Report .....	77
<b>Summary and Analysis</b> .....	78
<b>Attendees</b> .....	80



---

## INTRODUCTION

---

Over the past few years, there has been a tremendous revival of interest in airships. This seems to occur about every ten years, but what has surprised many is the duration and magnitude of the current wave of enthusiasm. In the early 70s, several articles were published emphasizing the airship's low noise and pollution and its potential for utilizing relatively undeveloped and inexpensive landing sites. Because aircraft noise and airport expansion were major issues at the time, many environmentalists added their support to the usual cadre of ex-airshipmen and aviation enthusiasts advocating airship revival. The energy crisis and the airship's fuel efficiency gave additional impetus to the movement, attracting more conservative elements of industry and government.

Simultaneous with renewed interest in the United States, several design projects were started in England, France, Germany and Canada, sponsored by such reputable firms as Shell International. A German firm has built several small airships recently and a Canadian airship will be flown within the year. A British group has flown a small recreational vehicle. Even the Soviet press announced design studies in progress in the USSR.

Add to these conditions a number of both vocal and articulate advocates and what might have been another brief period of popular interest has become a major topic of discussion. As a result, the United States Government is re-examining airships. The Senate Committee on Aeronautical and Space Sciences heard several LTA presentations during its hearings on Advanced Aeronautical Concepts. The Naval Air Development Center at Warminster, Pennsylvania, has begun an in-house study of current technology that could be applied to lighter than air. The National Aeronautics and Space Administration's Ames Research Center recently awarded two study contracts to analyze LTA concepts.

To focus these activities, NASA, the Navy, the United States Department of Transportation and the Federal Aviation Administration sponsored a one-week workshop on lighter than air. This program, organized and directed by the MIT Flight Transportation Laboratory, is documented in this report and FTL Report 75-2. *Proceedings of the Interagency Workshop on Lighter Than Air Vehicles*

## **The Workshop Concept**

Workshops have been used for many years to bring together a group of people knowledgeable on a particular subject for an intensive period of discussion and interchange of ideas. During the first part of the workshop, formal presentations are made to the participants. As many representatives of different perspectives and viewpoints as can practically be expressed are invited to participate.

During the latter part of the workshop, the participants form working groups to discuss and synthesize the presentations and add their own views and experience. They are expected to generate written reports documenting their discussions and conclusions. It is this output process that differentiates a workshop from the more typical technical conference.

These written group reports are then combined and edited by the workshop director and distributed to all participants for comment and review. The material is then revised to reflect participant feedback. The final report represents the consensus of the problems and issues raised at the workshop.

An important element of any workshop is the human chemistry that takes place during the program. After several days, the participants begin to shed their institutional personalities and react with the other participants on a more individual basis. Organizational barriers are lessened and eventually the person across the table is no longer a potential adversary from another company or agency.

To aid this interaction, a remote but attractive site is chosen. Participants are isolated from the day-to-day pressures of their offices and normal way of life so they can concentrate on the specific problem at hand.

The bringing together of people with different and



often conflicting interests and opinions in a manner that allows fuller, freer interchange may be the most important, though least tangible, accomplishment of a workshop. Most participants leave with a better understanding of the issues and a better perspective of the overall problems. The effects of this information exchange may not be felt for two or three years. When they are felt, people will probably no longer connect them with the workshop. But in the long run, the impact of a workshop may have far-reaching effects.

### **The Workshop on Lighter Than Air Vehicles**

This workshop followed the established pattern. It was held September 9-13, 1974, at the Naval Postgraduate School in Monterey, California. (In large part, its success was due to the interest and support of the school's staff, particularly Ruth Guthrey, Professor Donald (Red) Layton and his assistant, Michael Odell.) Over 230 participants attended all or part of the program. They came from universities, government agencies and the military, manufacturers, airlines and consulting firms. They included career civil servants, planners, lawyers, engineers, economists, marketing men, ex-airshipmen, etc. Many came at personal expense because of deep personal interest.

During the first three days, over fifty formal papers were presented. The working sessions filled the last two days. Sessions were scheduled from 8 in the morning until 10 at night and attendance remained high throughout the program. In fact, the workshop's success was due to the outstanding enthusiasm of all who participated.

## **HISTORY AND BACKGROUND**

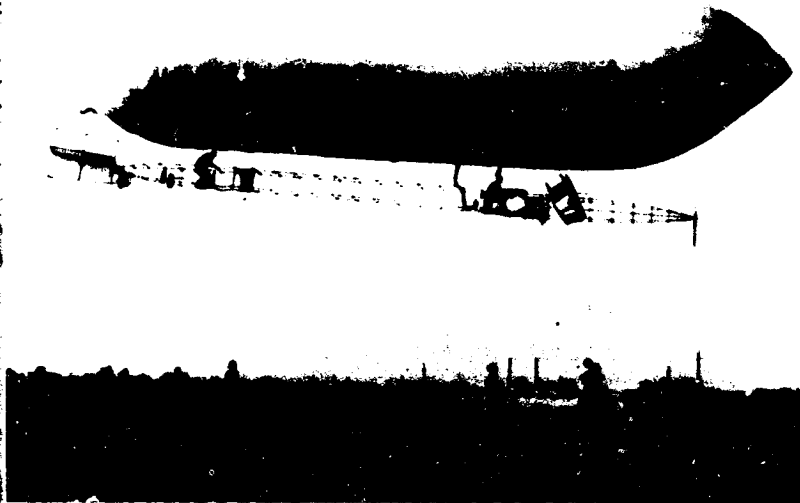
The concept of buoyant flight was first suggested in 1250 when Roger Bacon conceived of a hollow globe filled with "aetherial air" or "liquid fire" which would float in the atmosphere like a boat on water. However, he neglected either to define these mystical substances or to say how they might be obtained.

Five hundred years later, the concept was to become a reality. In the interim, other buoyant flight theories were proposed, but all suffered from an inability to obtain a lifting gas that was lighter than air. Then two different approaches were successfully tried within a very short time of each other.

### **Early Flight**

In 1782, the Montgolfier brothers captured smoke in a bag which then rose into the air. Soon they were flying large silk and paper constructions and in November, 1783, Jean-Francois Pilatre de Rozier and Marquis d'Arlandes stayed aloft for 23 minutes in a large Montgolfier bag, becoming the first men to fly. (M. de Rozier and Pierre Romain hold the dubious distinction of being the first recorded aviation casualties when their combined hot-air hydrogen balloon caught fire and crashed during an attempt to cross the English Channel in 1785.) Shortly thereafter, in December, 1783, Professor J. A. C. Charles made the first manned ascent in a hydrogen balloon. Drifting over Paris and the surrounding countryside for over two hours, he proved that extended flight was possible.

These early flights were full of adventure and excitement, but balloons would not have many practical applications until control and propulsion systems were available to make them steerable against the wind.



*Smithsonian Institution photo #A48184*

(The French word for steerable—"dirigible"—has become the generic term for all types of steerable lighter than air vehicles.) Many schemes were tried: gauze covered oars, hot air jets, even rockets were proposed. In 1852, Henri Giffard achieved limited success by driving a propeller with a three-horsepower steam engine of his own design. In 1884, Renard and Krebs used electric power to reach about 15 miles per hour. These airships were not particularly useful, however, because the weight of the power plants drastically limited payloads. It was not until lightweight gasoline engines became available in the 1890s that the basic development of the airship was completed.

### **Zeppelin and His Airships**

Although the French pioneered airships, the Germans made them practical. As early as 1874, Count (Graf) Ferdinand von Zeppelin was planning a series of large military airships. The Count had been told of the potential for airborne reconnaissance while a military

observer in the United States during the Civil War. The North used manned tethered observation balloons for several years and its victory at Fair Oaks in 1862 has been ascribed to information telegraphed down from a balloon during the battle. Zeppelin was also familiar with the Austrians' attempts to float explosive-laden balloons into Venice during the siege of 1849 and with the use of balloons to carry passengers and mail out of Paris while it was under seige in 1870-1871.

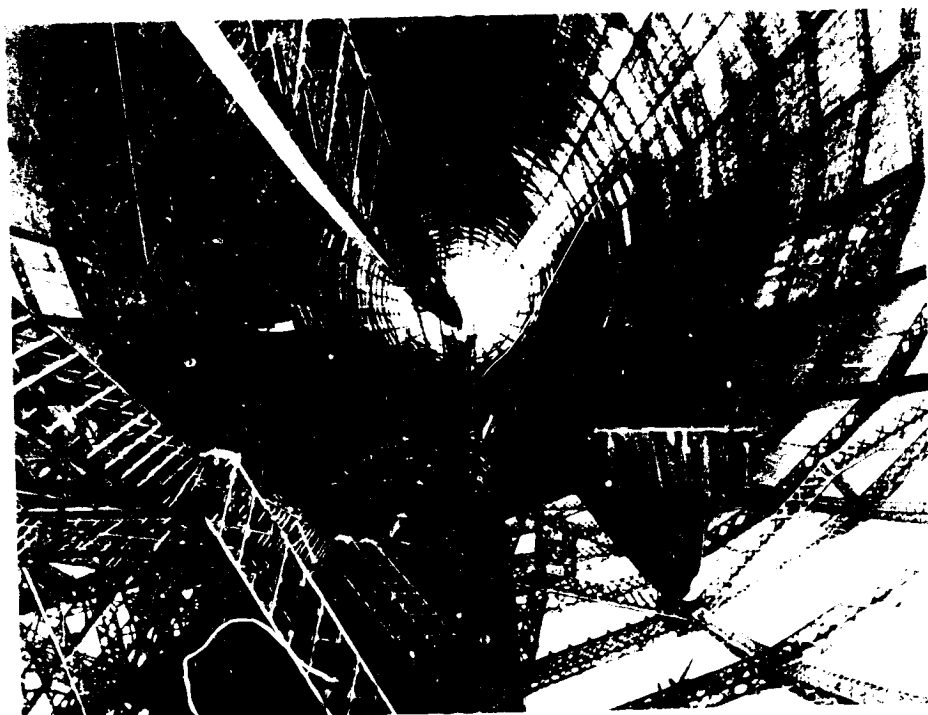
The Count realized that airships had to be big to be successful. And to be big, they had to be rigid. His basic design, completed in 1894, was for an airship over 400 feet long. Longitudinal girders were connected to circular frames which were then cross-braced with wire to achieve structural stiffness. Gas cells were installed between the circular frames and the entire structure was covered with fabric. With few exceptions all large rigid airships have followed Zeppelin's basic design.

Zeppelin's first airships were developed with the Count's own funds and public stock offerings. But twice the firm had to be saved from bankruptcy by lotteries sponsored by the King of Wurtemberg who was impressed by Zeppelin's early flights. It was not until the military became interested and provided adequate funds that development proceeded rapidly.

From the flight of the first Zeppelin in 1900 to the Count's death in 1917, the firm produced over 100 airships. Although most were military, several were placed in commercial service DELAG, the airline founded by Zeppelin in 1909, carried over 34,000 sight-seers and passengers before the outbreak of the war. Not many by today's standards, but more than U.S. airliners carried until 1929.

## **Airships at War**

Wartime Zeppelins were used for scouting and observation. But they also flew more than 50 bombing missions over England. Although approximately 560 British were killed directly by Zeppelin action, many more were killed and injured by falling anti-aircraft shells and airplane crashes as the defenders tried to drive off the airships. The resources committed to defense were many times greater than the Germans' in-



Smithsonian Institution photo #A49245

vestment in the raiders, tying up funds, equipment and manpower the English would have liked to deploy elsewhere.

As aircraft and anti-aircraft equipment improved, the Zeppelins were forced to fly higher and higher. Later versions could operate at over 20,000 feet with a seven and one-half ton payload, a remarkable accomplishment because airships are basically low altitude craft. But ultimately, improved airplanes and the use of incendiary bullets forced the hydrogen filled Zeppelins out of British skies and ended their use as offensive weapons.

Although England built several rigid airships during the war, the designs were always several years behind Germany, and not as successful. The British (and French) major successes were in the development of non-rigid airships (blimps) for coastal patrol and scouting missions. The Italians developed the semi-rigid airships (a blimp with a keel) for similar applications and for bombing. All of these craft were considerably smaller than the Zeppelins, with correspondingly smaller payloads and less endurance. However, they were less expensive and were built in quantity.

## **The Golden Age—The Period Between the Wars**

After the war, the Zeppelin Company built two passenger airships and reinstituted service within Germany. This was soon stopped by the Allies, however, and these two craft as well as the few remaining wartime Zeppelins were transferred to several of the Allied nations. (Many airships had been destroyed by their crews). This would probably have been the end of the Zeppelin story, but the United States, which had not received any of the existing airships, ordered a new airship from the Zeppelin Works after much negotiation with the other Allies and Germans alike. The Los Angeles, as this airship was known in the United States, kept the firm in business until the restrictions on Zeppelin construction were lifted.

In 1925, the Zeppelin Co. was allowed to build Zeppelins again and immediately started the design and construction of perhaps the most successful airship of all, the Graf Zeppelin. Named in honor of the Count, it was christened by his daughter on the 90th



From the Zeppelin Company's collection. #A-11-1

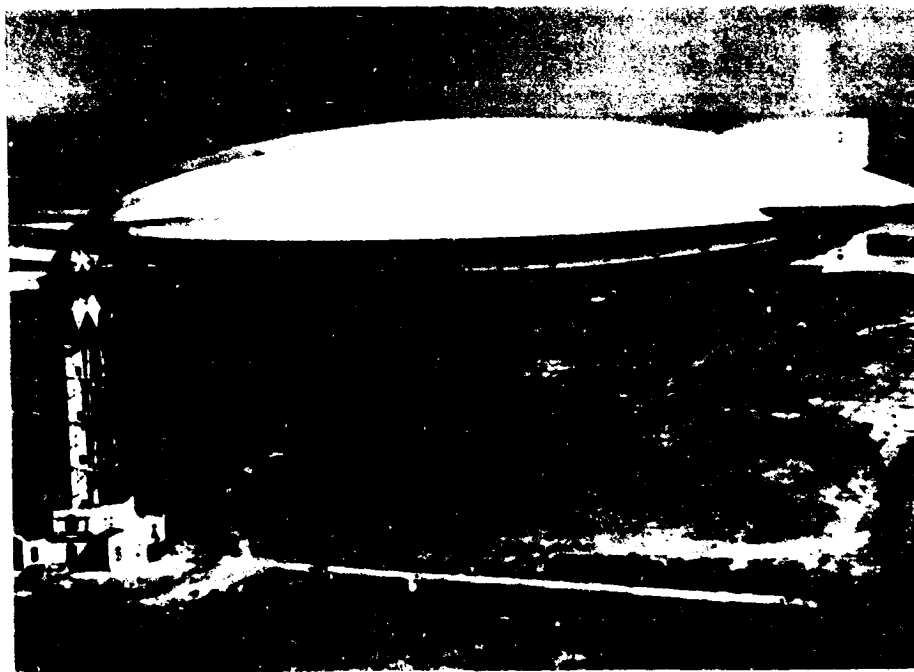
anniversary of his birth. This airship made 590 flights, flew over 1 million miles and spent over 17,000 hours in the air. As well as operating in regular service to South America, the airship made many special flights including the only around-the-world voyage by airship. Grounded after the Hindenburg disaster, the Graf (along with the Hindenburg's sister ship, the Graf Zeppelin II) was finally scrapped in 1940—twelve years after she entered service.

Most of the Allied nations lost interest in rigid airships after a series of disasters. Many of the Zeppelins transferred to them at the end of the war met violent ends as did rigids built by the Allies as copies of war-time Zeppelin designs. (In most cases, the losses were due to inexperience.) The United Kingdom and the United States were the only nations other than Germany to retain an interest in large rigid airships.

At the end of the war, the British had several rigid airships under construction. The most successful of these, based on a Zeppelin forced down in England in 1916, were the R33 and R34. The latter was the first aircraft to cross the Atlantic east to west and the first airship to make the west to east crossing. Both were first flown in 1919. The R34 was damaged in 1921 due to an operational error and never re-entered service. The R33 remained in intermittent use (as government policy toward airships fluctuated) until the end of 1926, making her the longest-lived British rigid.

The R38, started in 1918, was a bold extrapolation from Zeppelin designs. When completed in 1921 she was the largest airship in the world (699 feet long, with a 2.7 million-cubic-foot capacity). The airship was scheduled for sale to the United States but 17 of her American crew were killed along with 27 others when the R38 broke up during turning trials on her fourth flight. The changes had been too bold.

After the R38 disaster, British enthusiasm for airships waned for several years. Then in 1924 the British Rigid Airship Program was announced. Two large airships were to be constructed to provide air service to the far flung British Empire. The R100 was to be designed and built by the Airship Guarantee Company, a private firm. The R101 was to be developed in parallel by the government at the Royal Airship Works. Both had twice the gas capacity of the Graf Zeppelin, although they were designed two years before the Ger-



*Smithsonian Institution photo WA48315*

man craft. Neither flew until 1929, two years late and one year after the Graf.

The R101, as a government project, had political as well as technical problems. There was pressure to incorporate ideas which could provide substantial technological advances, if successful, but which had never been tried before. When completed, the R101 was too heavy and another bay had to be installed for additional lift. The engines were overweight and under-powered. In October, 1930, after a single 17-hour test flight of the new configuration, the R101 began its maiden voyage to India. It crashed and burned a few hours later in France, killing all but six aboard.

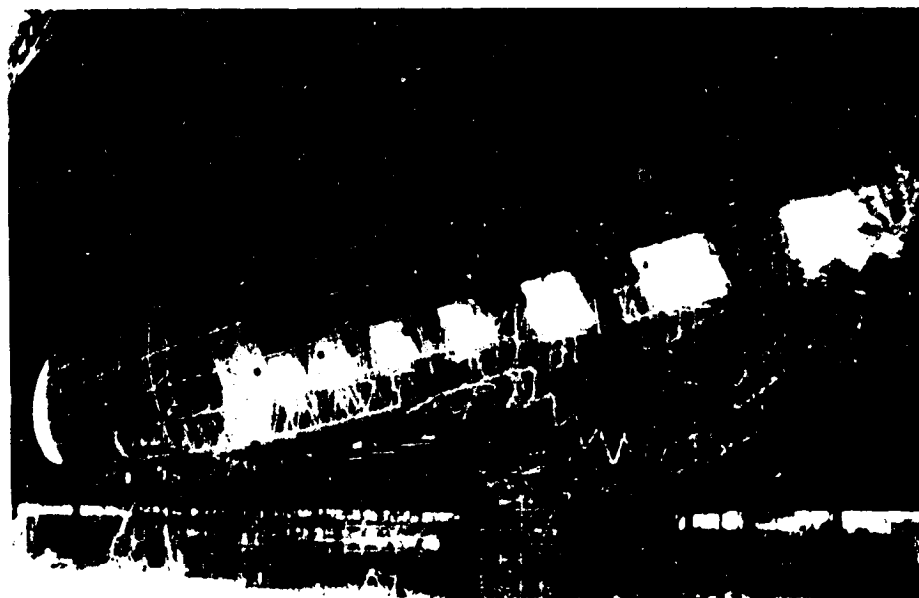
The R100 followed a more traditional design and had fewer problems. It had a top speed of 81 mph and surpassed most performance specifications. It completed its demonstration flight to Canada and back during the summer of 1930 and would probably have been a successful airship, but the deepening depression and the R101 crash spelled the end of official British interest in airships.



## Airships in the United States

The first successful American airship did not fly until 1904 when Thomas Baldwin built and flew his California Arrow, based on a Santos-Dumont design. Baldwin's almost identical Signal Corps #1 became the first United States military airship in 1908. But serious interest did not arise until 1916 when the success of the British non-rigid patrol airships encouraged the Navy to develop a similar vehicle. Several types were built and flown on coastal patrols off the United States. The Navy also operated British and French airships in Europe during 1918.

American interest in rigid airships was at its peak between the wars. In 1919, the Navy approved construction of the Shenandoah, based on a captured Zeppelin, and the purchase of the R38 from Britain. The loss of the R38 during its trials delayed the construction of the Shenandoah which did not fly until 1923. She led a successful career for almost two years until she broke up while encountering a line squall in Ohio in 1925. Fortunately, she was filled with helium, as were all U.S. rigid, limiting the loss of life.



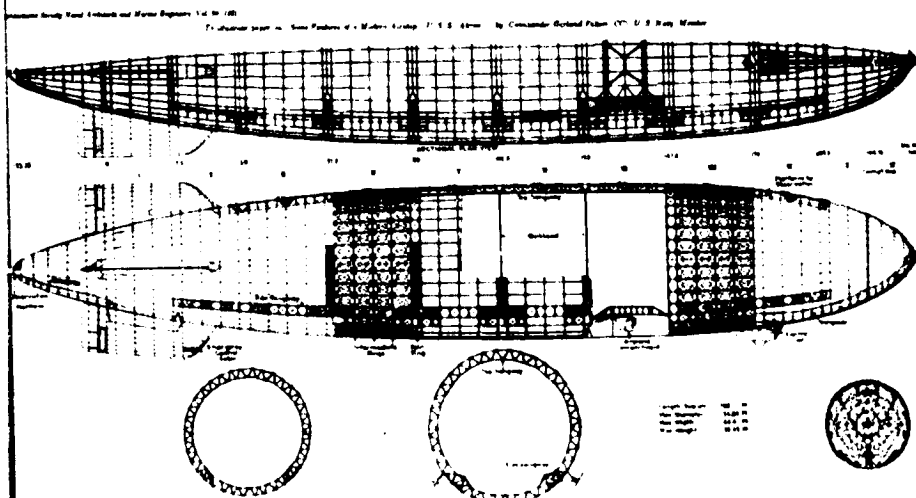
Smithsonian Institution photo #A4799A

11 REPRODUCED FROM  
ORIGINAL PAGE IS POOR

The structural failure could be blamed on two factors. First, the Zeppelin used for the Shenandoah's basic design was a "height climber", not designed for low altitudes or rough weather. Second, and perhaps more important, the severity of the turbulence was much greater than meteorological knowledge of the day could predict, stressing the ship far beyond her design limits.

The loss of the Shenandoah left the United States with the Los Angeles as its only airship. Purchased from the Germans in 1924, this ship led a long and successful career. It was flown for 8 years, making 331 flights of more than 5,000 hours total flying time. It was used 8 more years for ground and mooring tests until finally it was dismantled in 1940. Unfortunately, its success was overshadowed by the tragedies that followed.

In 1926, Congress authorized the Navy to build two rigid airships of 6,500,000 cubic feet—the largest ever. There was a competition and 37 designs were submitted. The award was made to Goodyear in 1928 and construction on the Akron, the first of the two sister ships, began in 1929 after a special 1,175-foot hangar was constructed.



R

In addition to their size, the two airships had another unique feature—an onboard hangar for five airplanes and the equipment to launch and retrieve them. Although experiments with launching and retrieving airplanes from airships had been carried on earlier in England and in the U.S., the Akron and Macon were the only airships ever designed as aircraft carriers.

During her 18 months in service, the Akron and its aircraft took part in several fleet maneuvers. But the Akron's success as a scout was limited by lack of experience on how to use the airship and its airplanes in the most effective, complementary fashion. These techniques were later developed with the Macon which was just beginning to prove its potential when it was lost.

In April, 1933, the Akron left Lakehurst, New Jersey, on its last flight. In attempting to avoid a storm area, the airship was inadvertently taken into its center. After several violent up- and downdrafts were encountered and survived, the ship was rapidly drawn downward, its tail struck the ocean and the entire ship broke up. The court of inquiry did not find fault with the airship. Rather, the loss was attributed to the inexperience of



*Smithsonian Institution photo #72-1852*

R

the captain, insufficient weather information, and perhaps the failure to correct the pressure-altimeter for the low pressure in the storm center. In all probability, the Akron had been at only 1000 feet rather than the 1600 indicated, giving a false sense of security. Only three of those on board were rescued.

The loss of the ship was a severe blow to the Navy's rigid airship program. Admiral William A. Moffett, Chief of the Bureau of Aeronautics and staunch supporter of the rigid airship program, was on board and lost with the ship, as were many of the Navy's best airshipmen. If the Akron's sistership, the Macon, had not been ready to fly within weeks, the entire program might have ended.

Less than three weeks after the Akron's loss, the Macon made its maiden flight. After initial trials and acceptance flights, the Macon was ultimately flown to Sunnyvale, California, which was to be its home base, and began operations with the Pacific fleet. The Macon was flown east again in 1934 to participate in fleet maneuvers. During this flight, it was buffeted by severe turbulence, while greatly overloaded, and the combination of rough weather and violent maneuvers needed to keep the airship under control severely strained the structure at the points where the fins joined the hull.

Temporary repairs were made and a reinforcement program initiated. By February, 1935, this program was complete except for the area where the upper fin joined the fuselage. All repairs had been made without taking the Macon out of service. The top fin strengthening, however, required deflation of a gas bag and therefore was not planned until the next normal overhaul scheduled for March. No one considered the condition unsafe.

But, while returning from maneuvers on February 11, 1935, the Macon encountered severe turbulence and the top fin tore away at the weakened point. Several aft gas bags were punctured by the debris and ballast had to be dropped to counteract the loss of lift. The Macon then became light, and engines still running, rose rapidly above pressure height, lost more gas and then settled gently to the sea. Only two lives were lost, and those needlessly, but the disaster spelled the end for rigid airships in the United States.



*Smithsonian Institution photo #A945*

## **The End of an Era**

Shortly after the completion of the Graf Zeppelin, the Germans began the design of a larger airship to operate in commercial service with the Graf. Because the new airship would have a capacity of almost 5.5 million cubic feet construction was delayed until a new, larger hangar could be built. Before this hangar was completed, however, the R101 disaster convinced the Germans that the new ship had to be inflated with helium. Therefore, the original design was put aside and a new design begun.

Due to the lower lift of helium, the new airship was even larger than the originally proposed aircraft. More than 800 feet long, it had a capacity of over 7 million cubic feet. But the United States, which had a monopoly on helium, refused to sell it to Nazi Germany because of its potential military use. Therefore, when this new airship, the Hindenburg, made its maiden flight in 1936 it was inflated with hydrogen. Just over one year later, on May 6, 1937, the hydrogen exploded while the Hindenburg was landing at Lakehurst and commercial airship service abruptly ended.

The Hindenburg's sister ship, the Graf Zeppelin II, made its first flight 16 months after the accident at Lakehurst. Because helium was still not available, it was not placed in commercial service. German authorities made 30 experimental flights with the airship, many to probe the new British radar defenses. The Graf II was dismantled along with the original Graf in 1940 and the scrap was converted to other military uses.

## Blimps at War

Although the Navy's major interest was in large, rigid airships during the period between the wars, the role of blimps in the first world war was not forgotten. In addition, Goodyear continued to manufacture blimps for its own commercial and advertising purposes. Therefore, when the Nazis overran France in 1940 and established submarine bases on the Atlantic, the Navy contracted with Goodyear for four new blimps, all twice the capacity of World War I models. The first airship patrol group was commissioned at Lakehurst in January, 1942. By the end of 1943, almost 100 airships were flying.

Convoys with blimp coverage were rarely attacked. Approximately 89,000 ships were escorted without the loss of a single ship to enemy submarines. But, despite this record of service, many airship groups were disbanded and their bases were decommissioned immediately after the war.

Navy interest in blimps continued at a lower level into the 1950s when several new and larger types were introduced. During the end of the decade, blimps were used as part of the early warning radar chain. The last of these radar blimps had a 1.5-million-cubic-foot



*Smithsonian Institution photo #72 6650*

capacity and was 408 feet long with a 40-foot radar scanner inside its envelope.

By 1960, the introduction of more powerful land-based radars and long-endurance airplanes outfitted for anti-submarine warfare spelled the end of the blimp fleet. Over the next two years, the remaining airships were decommissioned and the last airship group was disbanded in 1962.

### **The Decade 1964-1974**

Following the phase-out of the Navy's blimps, Goodyear's small advertising blimps were the only airships still flying regularly. A few surplus blimps were intermittently flown in Europe and Japan for advertising and promotional use, but the day of buoyant flight seemed over.

Then during the early 1970s there was a resurgence of interest. Actually, interest never totally ceased. Rather, it periodically went underground to re-emerge about every 10 years with renewed vigor. What has surprised many is the duration and extent of the current interest.

Offered first as alternatives to aircraft noise and pollution, airships captured the interest of the environmentalists as well as the usual cadre of ex-airshipmen and aviation enthusiasts. The energy crisis and the airship's fuel efficiency gave a second wind to the movement and began attracting more conservative elements of government and industry. Design projects and flight test models have been produced in several countries and a number of larger vehicles are under construction (although these are small compared to the earlier rigids).

Add to these conditions a number of both vocal and articulate advocates and what might have been another brief period of popular interest has become a major subcurrent in aeronautics today.

As a result of this high level of interest and discussion, several federal agencies are re-examining the potential of lighter than air. To provide a focus for the work, the National Aeronautics and Space Administration, the Navy, the Department of Transportation and the Federal Aviation Administration sponsored the workshop which is the subject of this report.

## **THE WORKSHOP REPORT**

After three days of presentations, the workshop participants formed five working groups to discuss the information presented and to apply their own expertise to the various aspects of buoyant flight. Ideally, these groups should have come to preliminary positions and then exchanged members with other groups to cross-pollinate ideas and coordinate results. However, due to time constraints and the large number of topics to be covered, interaction was limited to a few general presentations by each working group to the participants as a whole. The draft reports of the working groups were distributed to all participants, after the workshop, for review and comment. In most cases, responses have been incorporated in this final report. Significant modifications and the reasons for them are outlined in the next chapter, along with other comments deserving special attention.

### **Policy Working Group**

The original goal of the Policy Working Group was to suggest LTA policy options that the United States might pursue and to outline the impacts of various courses of action. However, the group felt that such a broad approach could not be taken in the limited time available and chose to outline a more specific policy "statement" instead.

The major issues addressed by the working group were:

Should the United States government develop lighter than air vehicles?

Should the United States government sponsor



R

lighter than air research and technology efforts, including the construction of experimental LTA vehicles?

The group identified civilian and military missions unique to LTA (e.g., transporting heavy powerplant components to remote sites or loitering on station for long duration surveillance) and certain competitive missions for which LTA is well suited but which are now performed by other modes (e.g., carrying heavy cargo over water). They explored possible export-import implications in LTA technology, as well as potential energy savings and improvements in the United States military posture. Due to the unknown economic risks, the group concluded that government development of an LTA vehicle would be premature. Rather, they felt that appropriate agencies of the United States government should encourage LTA research and technology and should sponsor appropriate studies to better define LTA's technical and economic unknowns. R&T should not, however, be confined to the government—private industry and universities were also encouraged to study these fundamental areas of uncertainty. Construction of experimental LTA research vehicles can only be justified after these additional studies have put some limits on the risks involved.

Additional issues discussed were:

What is the proper role, if any, of LTA in civil transportation? In military missions?



Who should assume the costs of any required infrastructure to support LTA operations?

What type of LTA vehicle is the most promising: non-rigid, semi-rigid, rigid or hybrid? With metal-clad or traditional coverings?

What is the best way to estimate the economics of airship operations? The cost of construction?

The working group felt that LTA's major role is for cargo, not passenger transportation. There is a civilian need for heavy lift capability as well as for the movement of goods and commodities at rates and speeds between those of surface modes and current airplanes. There is a military need for transporting military cargos, lifting goods from ship to shore and staying on station for long durations. Although everyone supported the theory that the United States government should assume responsibility for LTA air traffic control as it does for heavier than air (HTA) vehicles, there was little support for federal funding of other infrastructure items such as hangar and/or special airfield construction (although some felt that ADAP funds could be used for these purposes). Indirect mail subsidies were discussed, but the majority felt that the cost of running an airship line should be borne largely by its investors.

There was no consensus as to which type of LTA was best. Rather, each type seemed to claim its own position in the LTA spectrum.

There was almost universal agreement that only the actual construction and operation of an airship could provide adequate answers to economic questions. Extrapolations from past LTA experience, while possibly adequate in some areas, could not be used to estimate today's operating or construction costs. However, studies of potential markets and missions (as well as possible technical innovations) could bring investment risks to an acceptable level before a construction program might begin.

Having considered all these factors, the working group developed a policy statement which was endorsed by a majority of the workshop's participants. If the results of the programs outlined in these recommendations support the potential of LTA, a flight research program would be the next logical step in the revival of lighter than air systems.

## **Workshop Policy Statement**

Lighter than air systems have certain inherently attractive characteristics, including:

Low dependence on prepared facilities and rights of way

Unique ability to transport large indivisible loads

Unequalled airborne endurance on station and en route

Low fuel consumption and minimal environmental impact

These characteristics give LTA the potential for solving such national and international transportation problems as opening up inaccessible regions for agriculture and the development of natural resources, onsite delivery of modular housing and large powerplant components, and anti-submarine and surveillance missions for the military. In addition, LTA could supplement current systems for cargo transportation, environmental monitoring and social services, such as disaster relief. Foreign sale of lighter than air vehicles and components would also help the United States balance of payments.

Although LTA systems could provide enormous benefits to the United States and the world, they may cost hundreds of millions of dollars to develop and implement. Therefore, to minimize the technical and economic uncertainties prior to committing such large sums, the following actions are recommended:

### **TECHNOLOGY**

Current technologies in aeronautics and related fields should be surveyed to determine what knowledge may be directly transferable to lighter than air systems.

Lighter than air projects in progress or contemplated by foreign governments and companies should be surveyed to identify common areas for international cooperation.

A technology assessment of lighter than air systems

should be performed, specifically analyzing comparative energy consumption, land use, noise and air pollution and other environmental impacts for a broad range of LTA applications.

Lighter than air analysis should be introduced into academic programs and the theoretical study of LTA encouraged through fellowships and financial aid.

#### **MARKET ANALYSIS**

A broad survey of unsatisfied transportation needs should be conducted to identify commercial markets and military missions where LTA might offer a unique solution and to estimate the rates at which service would be attractive to consumers.

Cost, volume, service and performance characteristics should be identified for a range of commercial markets and military missions currently served by existing transportation modes, and estimates made of what LTA would have to offer in order to penetrate these markets.

The transportation problems of developing countries and LTA's potential for solving them should be given separate attention.

#### **GOVERNMENT POLICY**

A mechanism for the exchange of information between potential users and potential manufacturers should be established with a central clearinghouse for LTA-related information.

Government agencies should include an LTA element in all future transportation studies.

Appropriate agencies should develop incentives to stimulate broad interest in LTA in the private sector. This could include a program of modest government grants for concept development and elaboration as well as possible cost sharing programs between government and industry.

Certification, licensing and operating rules and regulations for LTA vehicles and crews should be reviewed, revised and developed where needed to allow rapid progress in the private sector unhampered by unnecessary technicalities.

The helium conservation program should be reviewed to preserve this rare element essential to progress in LTA systems and other technologies as well.

## Market Analysis Working Group

Commercial success of LTA will be measured by profits; military success by effectiveness in satisfying mission requirements. Before success can be predicted, LTA missions or markets must be identified and the vehicle characteristics specified. The number of vehicles that might eventually be needed can then be estimated and production, research and development costs amortized over expected sales to determine vehicle prices. Thus, identifying potential LTA markets and missions is important not only as a mechanism for identifying the type of vehicle and its important features, but also as the first step in determining its economics.

The objectives of the Market Analysis Working Group were to:

- Identify possible missions and market opportunities for lighter than air craft

- Evaluate relative value of mission/market applications

- Indicate primary areas for lighter than air vehicle development and application

The steps taken to reach these objectives were to:

- Establish mission/market categories

- Detail the missions and markets in each category

- List the commodity and transport attributes which should be evaluated for each category

- Identify major LTA vehicle types

- Select the LTA vehicle types which could be used for each mission

- Identify high potential applications

- Use the above to select major missions/markets for each of the four major LTA vehicle types



#### **MAJOR MISSION/MARKET CATEGORIES**

The working group reviewed the possible commercial, military and public service uses for LTA vehicles. Major market categories were:

Heavy-lift, large-size unit movements

Agricultural applications (harvesting crops, transportation from the field and other services)

Passenger transportation

General cargo transportation (particularly low density products over transoceanic routes)

Bulk transportation (dry, liquid and gaseous)

The more specialized, non-market-oriented missions identified were:

Military missions (anti-submarine warfare (ASW), logistics support, etc.)

Special missions (public service, non-load carrying applications, traffic control, communications, etc.)

Environmental surveillance

## THE MISSION/MARKET MATRIX

In the mission /market matrix (Table 1), the missions are representative of those which could be performed by LTA systems and are grouped into the categories discussed in the previous section. Within each category the missions are listed in order of decreasing potential based both on the size of the market and its suitability to LTA.

The matrix indicates that four separate types of LTA craft may be needed:

Tethered balloons

Heavy lift, short range, VTOL airships

Fully buoyant airships

Hybrid airships

A fifth type of airship, not considered in detail, was a surveillance craft. This is actually a small airship or hybrid not capable of long range or heavy lift but used instead as a platform. It was eliminated because it was not fundamentally a different type of craft.

The matrix indicates that each type of vehicle has potential for a wide variety of applications. The degree to which LTA can penetrate these markets will depend on LTA performance and costs in competition with other systems. In many of the missions, LTA would capture only a small portion of the total market (e.g., the transportation of dry bulk goods and agricultural commodities). LTA could, however, capture large shares of local markets, particularly in regions where alternate modes of transportation are undeveloped.

Most potential LTA applications require vehicles of large size and payload capability. These will be expensive to develop. On the other hand, some applications for relatively small vehicles are possible, such as for patrol, surveillance and personal use. Development of these vehicles would be relatively inexpensive and might be a logical first step in re-introducing LTA.

## COMMODITY MARKET ATTRIBUTES

The characteristics of the commodity to be moved influence the choice of vehicle and/or its design. The

TABLE 1  
POTENTIAL LTA MISSIONS/MARKETS

	Tethered Balloon	Heavy Lift Short Range VTOL	Fully Buoyant Airships	Hybrid Airships
<b>MILITARY</b>				
Anti-submarine warfare			X	X
Over the shore logistics support	X	X	X	X
Command control center			X	X
Strategic lift			X	X
Communication	X		X	X
Surveillance		X	X	X
Minesweeping			X	X
Missile launching platform	X	X	X	X
Heavy lift tactical support			X	X
Sea control			X	X
Rescue and recovery	X	X	X	X
Ship repair		X	X	X
Navigation aid - maintenance		X	X	X
Aircraft and RPV carrier			X	X
Hospital Airships				
<b>HEAVY LIFT OR LARGE SIZE</b>				
Prefabricated buildings	X	X	X	X
Power generation and transmission equipment	X	X	X	X
Construction services	X	X	X	X
Industrial equipment			X	X
Refineries tanks		X	X	X
Aerospace vehicles & components		X	X	X
Construction equipment	X	X	X	X
Mining equipment		X	X	X
Industrial duct works	X	X	X	X
Earthmoving	X	X	X	X
Offshore platforms		X	X	X



AGRICULTURE					
Timber harvesting and transport	X				X
Fresh fruits and vegetables, especially perishables					X
Livestock					X
Fish surveillance, harvesting, transport					X
Chemical application					X
Agricultural machinery movement					X
Crop harvesting in difficult terrain	X				X
Blight surveillance	X				X
DRY BULK					
Grain					X
Ore					X
Lumber					X
Coal					X
LIQUID BULK					
Petroleum and derivatives					X
Industrial liquids					X
GASEOUS BULK					
Natural Gas (Methane)					X
Ammonia					X
GENERAL CARGO					
Low density freight					X
Freight all kinds, unutilized origin to destination service					X
Vehicles (autos, trucks, etc.)					X
Warehousing logistic support					X
PASSENGER MOVEMENT					
Intracity rapid transit					X
Ambulance and wrecker					X
Individual (recreational vehicles)					X
Auto ferry				X	X
Fire fighters				X	X
Cruise ships					X
Scheduled passenger service					X
Special work site access				X	X

REPRODUCIBILITY OF THE  
ORIGINAL PAGE IS POOR

R

following have been selected as being the most pertinent:

Value per pound (market value of the commodity)

Density (weight per unit volume of the packaged commodity)

Size (overall dimensions of the unit to be transported)

Weight (weight of the indivisible unit to be shipped)

Environment (environmental requirements for the commodity during transport)

Shelf life (permissible transport time under the environmental conditions in the vehicle)

Fragility (vulnerability of the packaged commodity to damage)

In addition to the characteristics of the commodity itself, other factors influence a shipper's modal choice. The most important of these are:

Annual use volume (predicted yearly volume moving from the point of origin to its point of use)

Inventory control (warehousing and delivery requirements)

Transport margin (difference between the production cost and market price which cannot be exceeded by transport cost)

Accessibility to transportation (the need for door-to-door pickup and delivery)

Security requirements (the need for security relative to pilferage or outside access)

In a complete market analysis these factors must be evaluated for each potential market.

## REQUIRED TRANSPORT ATTRIBUTES

To match missions/markets with LTA capabilities, vehicle and system characteristics must also be defined. The major factors to consider are:

Vehicle performance parameters (payload weight, cruise speed, range, altitude, endurance, ability to hover/loiter, take-off and landing characteristics)

Cargo capability (dimensions of largest indivisible component that can be handled, weight of largest indivisible component, ability to provide refrigerated environment, ability to provide low vibration environment)

Transport system effectiveness parameters (time reliability, dependability of schedule, security from pilferage, need for terminal support facilities and manning, door-to-door capability, frequency of service, cost of transit)

Environmental impact considerations (noise, air pollution, energy efficiency)



Sensitivity to the external environment (vulnerability to snipers or military actions, weather sensitivity, radar signature)

### THE ANALYSIS PROCEDURE

With the preceding information, it is possible to match vehicle types and possible markets to identify those combinations with the highest potential for development. The working group did this qualitatively as a first attempt at market analysis. A much more detailed study is required for definitive answers. Each market must be addressed individually to assess the degree of market penetration and estimate the number of vehicles needed. This is an iterative process because vehicle costs, which are a major factor in estimating market potential, are dependent on the capital and operating costs, which are, in turn, dependent on the number of markets where the vehicles can be used.

For missions and markets not now being served, the estimation of the number of vehicles required is essentially a guess based on a knowledge of the production process and now it might be changed by LTA vehicles with the right characteristics. For existing markets, the analysis is based on tradeoffs between the costs and performance of the existing mode and the new LTA service.

### MISSION/MARKET ANALYSIS RESULTS

The following sections discuss the missions and markets each type of LTA vehicle might serve in the future.

**Tethered Balloons**—The market analysis in Table 1 indicates that tethered balloons would have particular applications as heavy lift devices in the ten to four or five hundred ton payload range. Balloon systems are currently being operated in the Bahamas as a communications platform and in the Pacific northwest by the Bohemia Lumber Co. and Alaska Lumber Co. for logging. The four logging balloons have 500,000 cu. ft. capacity and the aerial communication platform, 250,000 cu. ft. Payload is roughly 6.5 tons per 250,000 cu. ft. The balloon can be tethered and winches and various other equipment attached in several ways de-

R

pending on the application. The units are inexpensive and require very little research and development for new applications. The cost of the communication platform operated in the Bahamas is estimated at one million dollars, including the all-weather aerostat, winches and accessories. The logging systems cost 400,000 to 750,000 dollars.

Tethered balloons could be used in the future to spot-lift industrial and mining equipment and to move and set up prefabricated buildings and systems in lieu of a crane. They could be used as an earth-moving tool and have special applications in fire fighting as a lighting platform. Equipment movement over rough terrain is another possible application, as is service as a platform for aerial photography. As an agricultural tool, heavy lift tethered balloons could be used for blight surveillance, crop harvesting in difficult terrain and moving crops in and out of large fields. Another application could be in pipeline and transmission line construction where LTA can be used over difficult terrain with minimum disturbance.

Tethered balloons have various military applications as well: transporting supplies from ship to shore, moving heavy military equipment, repairing ships at sea or on shore where other facilities are not available, serving as military communication and surveillance platforms and providing heavy lift tactical support.

The United States government has recently spent a great deal of money on tethered balloon applications. The Range Measurement Laboratory at Patrick Air Force Base has spent about eight million dollars to develop a balloon system that could survive 90 knot winds. The resulting design has successfully flown in 85 knot winds and in all weather conditions. This work is a major advancement in balloon design and engineering and could lead to other industrial applications and missions, including adapting this new balloon to logging systems.

**Heavy Lift VTOL**—A major market exists for a heavy lift Vertical Take-Off and Landing (VTOL) aircraft to transport and place heavy or bulky loads for a wide range of applications from powerplant construction to mass transit. In many cases, the existence of an economical heavy lift VTOL aircraft would open up new market areas, such as mass production of prefabricated



housing, by offering a transportation service not currently available. LTA could be the answer. LTA VTOL could also be used in many military missions where existing methods do not offer adequate service. An example is the off-loading of container ships. With the replacement of break bulk cargo freighters by container ships, some new method must be found to unload the materials needed to support amphibious assault operations, either offshore or in ports where cranes are not available.

Table 2 outlines potential markets for VTOL LTA vehicles. None of the individual configurations presented at the workshop were specifically endorsed but general vehicle characteristics were developed. The air-

craft must have vectorable thrust substantially in excess of conventional airships, vertical take-off and landing capabilities and payloads ranging from 50 to 1000 tons. Low forward speeds are adequate for economic performance considering the short range normally associated with these missions.

In summary, a major market exists for heavy lift VTOL services for payloads that only LTA can lift economically. Several design concepts have been analyzed in detail. The results indicate that financially successful operational vehicles can be produced for these missions. In fact, they may be able to compete for some missions currently performed by other modes. The next step in these programs should be actual vehicle development rather than further study.

**Fully Buoyant Airships**—Different sizes of fully buoyant airships would be needed for different missions. Modern versions of past airships, small compared to those suggested today, would satisfy most military applications such as sea control, anti-submarine warfare and detection and command and control. These missions require the long duration, medium speed and loiter capabilities associated with buoyant airships. Present technologies in materials, propulsion and controls should lead to significant improvements over past design.

Agricultural missions in regions with undeveloped infrastructures may also be satisfied by these airships. Possible missions include the movement of farm products, including animals, from remote areas to transportation centers or directly to market. However, it is not clear that all of the design problems associated with this type of application can be overcome today.

Other applications require large LTA vehicles. Airships of 10 to 50 million cubic feet or larger could carry large payloads such as containerized general cargo or bulk cargos. The key question is the cost per ton mile for this service. The largest portion of that cost will be the amortized capital costs, therefore, a low initial cost vehicle must be developed.

The carriers who would use large airships can be subdivided into scheduled carriers and nonscheduled or chartered carriers. The scheduled carriers would develop adequate ground support services for mooring, fueling and loading at the points they regularly serve.

**TABLE 2**  
**POSSIBLE MISSIONS FOR VTOL LTA VEHICLES**

<b>MILITARY MISSIONS</b>	
<b>Primary</b>	
Over-the-shore logistic support	
Support of amphibious operations	
<b>Secondary</b>	
Marine navigational aid maintenance	
Mine sweeping	
Missile launch platform	
Heavy lift tactical support	
<b>COMMERCIAL HEAVY LIFT MISSIONS</b>	
<b>Primary</b>	
Transport and emplacement of power generating equipment	
Transmission and pipeline construction	
Transport and emplacement of industrial equipment such as cranking towers and large tanks	
Transport of construction or mining equipment to remote or normally inaccessible sites	
Transport and emplacement of mass produced, full sized homes and buildings	
General construction services such as mechanical equipment emplacement and bridge and overpass construction	
Transport of oversized aerospace vehicles and components	
<b>PASSENGER TRANSPORTATION</b>	
<b>Primary</b>	
Urban mass transit	
<b>Secondary</b>	
Transport of fire fighting personnel and equipment	
Ambulance and wrecker service	
Aerial 'auto ferry' service	
Transportation of workers to remote work sites	
<b>AGRICULTURE</b>	
<b>Primary</b>	
Timber harvesting	
Livestock transportation	
<b>Secondary</b>	
Chemical application	
Fishing	
<b>SPECIAL MARKET AREAS</b>	
Forest fire fighting	
Disaster relief	



However, the air charter or nonscheduled carrier must operate with minimum ground support services and will have to carry much of the equipment onboard. The resulting lower payload would have to be offset by premium rates for these special services.

Further market research is needed to define the market potential of all sizes of fully buoyant airships before prototype development is undertaken.

**Hybrid Airships**—Hybrid airships are vehicles which combine substantial aerodynamic lift with buoyant lift. These vehicles must either make a take-off run to generate airfoil lift or used vectored thrust and/or a rotary wing configuration to achieve vertical take-off capability. Like fully buoyant airships, hybrids could come in all sizes.

Several primary missions were foreseen for hybrids. The first is bulk commodity movement, principally in regions lacking a developed transportation infrastructure. This application includes the transport of petroleum, natural gas, dry bulk (ores, grains, lumber), livestock and fresh fruits and produce.

A second application is the transport of heavy out-sized loads such as power generation equipment, industrial and agricultural equipment and aerospace vehicles and components.

General heavy cargo applications in the industrialized world were identified as the third major use of hybrids. This would require penetration of surface-freight markets like feeder line container movements to or from long haul carriers; unitized origin-destination freight; low-density, high volume manufactured products such as plastics; automotive equipment and automobile components and breeder livestock.

Military missions where a medium to large hybrid could be used include long-endurance flights requiring both high-speed rapid deployment and low-speed maneuvering. Examples are anti-submarine warfare missile launching platforms and the strategic deployment of personnel, weapons and support equipment.

Small hybrids could perform surveillance missions combining long loiter with medium cruise speed capability such as environmental monitoring and border, police, coastal and pipeline patrol.

Vertical/Short Take-Off and Landing (V/STOL) hybrids might perform many short or medium range

airplane and helicopter missions, but with fewer constraints on payload weight, volume, energy and runway requirements. Similarly, V/STOL hybrids might also perform most long distance airship transportation and long endurance missions without being subject to the general wind and terminal-area operational constraints of fully buoyant vehicles.

Although preliminary economic analysis for V/STOL lifting-body airships indicates they might compete successfully for medium and short range airplane and helicopter missions, there are other hybrids about which less is known. Therefore, further technical, economic and market analysis is called for.

### Economics Working Group

The Economics Working Group attempted to formulate costing techniques for LTA vehicles and found that in general the costing and economic frameworks developed for fixed wing aircraft or other transportation systems are applicable to LTA. Statistical methods used by other modes are available to develop cost formulas from operating data, as are sensitivity analysis techniques to examine different alternatives and assumptions. Unfortunately, no LTA vehicles have been designed and built for many years and no modern operating experience is available. Therefore, there is no data base to which the costing techniques can be applied.

The following example illustrates the problem. The Air Transport Association's 1967 formula (ATA 67) for estimating comparative direct operating costs of turbine-powered transport airplanes uses the equation

$$C = a(\text{TOGW}_{\max}/b) - c 1/V_b$$

to estimate flight crew costs, where

$\text{TOGW}_{\max}$  = Maximum Gross Take-Off Weight  
of the Aircraft

$V_b$  = Block Speed

the constants a, b and c are derived from actual crew contracts

To estimate flight crew costs for a proposed aircraft, one inserts the  $TOGW_{max}$  and the estimated block speed, which can be computed from aircraft speed. By varying  $TOGW_{max}$  and  $V_b$ , parametric studies of crew cost versus aircraft weight and speed can be performed.

Applying this approach to airships, however, is impossible. Even if size and speed are given for a particular design, there is no data base that can be used to derive a, b and c, so they must be assumed.

Applying different sets of assumptions as to crew cost and other costs as well (all of which were quite reasonable), the range for LTA costs is between 2 and 30 cents per ton-mile. In one case, the airship would be highly competitive. In the other, there would be little market for its services. The group was able to decide, however, that the basic ATA 61 costing approach could be applied to airships if and when data is developed. The only major change is the addition of a gas replenishment term, unique to airships.

For most transportation modes, the annual capital cost represents a large percentage of total cost. Vehicle price, based on construction and development costs, is the main factor that determines annual capital cost. But this is an area where the working group encountered the largest variations in cost estimates.

These differences arose from inadequate information on the economic conditions under which early dirigibles were developed compared to the present economic situation, lack of experience with LTA craft under modern certification regulations and inability to define the complexity of a modern airship structure relative to current airframe experience. The latter factor is critical because aircraft manufacturing costs vary from \$10/lb. of airframe weight for simple, austere, "light" aircraft structures to over \$100/lb. for sophisticated transport aircraft.

Present estimates of LTA construction costs vary by orders of magnitude. It was possible to narrow this range to between \$25 and \$100 per pound of airframe weight although not without dissention. These estimates were not particularly sensitive to the number of airships produced—that is, there would be a relatively flat learning curve. To determine total cost, the research and development costs and the costs of prototype construction, testing and certification must be



pro-rated over the total number of units. Vehicle cost also influences insurance, direct airframe maintenance, general and administrative costs. The calculation of annual capital cost per ton-mile is also influenced by useful LTA life, utilization, financing conditions, opportunity cost of capital and tax shelter considerations. Given the lack of hard data in most if not all of these categories, the difficulties in estimating annual capital cost become obvious. (It should be noted that while the state of knowledge of airship costs is poor, the situation concerning hybrid LTA vehicles is even worse.)

Construction and operation of a prototype is the only way to obtain accurate LTA cost estimates. Short of this, studies should be directed toward examining potential markets for LTA in the existing transportation world. By analyzing the existing competition for potential LTA markets, cost and performance requirements can be derived at which LTAs would be economically feasible. By "working backwards" in this way, one can try to design an airship which will not exceed these costs.

In conclusion, the group identified a need to establish a hard data base for modern LTAs, with particular emphasis on construction and development costs. Given this data base, a set of equations can be derived and used to calculate cost and performance characteristics for various missions. However, actual opera-

tional experience will be needed to obtain this hard data base.

## **Operations Working Group**

The Operations Working Group concentrated on conventional airships and did not discuss hybrids. Their operation would perhaps resemble airplanes and helicopters more than classic airships. Ground operations and flight operations were treated separately although any given mission includes both.

### **GROUND OPERATIONS**

Ground operations were in two sub-categories: those incident to flight such as take-off, landing and mooring; and those not related to flight such as servicing, maintenance, loading and unloading. The general conclusion was that sufficient experience and technology exists to handle a large non-rigid such as the 1,500,000 cubic foot ZPG-3W blimp flown by the U.S. Navy from 1958 to 1961. This technology and applicable procedures would also be adequate to handle a small rigid up to perhaps 3,000,000 cubic feet, but beyond that size larger and heavier equipment would be required.

Although the technology and procedures developed for the ZPG-3W were adequate, the group felt that a flight research airship would be an invaluable tool for refining operations to commercial standards and investigating possible solutions to in-flight operational problems.

The two types of mooring masts used with the ZPG-3W could be used with large non-rigid or small rigid airships—the mobile mast and the transportable stick or expeditionary-type mast. (The stick-type are less expensive.) Mechanical ground handling could be done with a mobile winch (as with the ZPG-3W), which could also tow the mobile mast. In pairs, mobile winches could be used for docking and undocking, masting and unmasting and landing and launching, reducing ground crew requirements to eight to ten men. Ground crew requirements for any size ship should not exceed this number.

At a mooring out circle, a jacked and dogged down

mobile mast with a ZPG-3W moored to it could hold in winds of up to ninety knots. Although docking and undocking of this size airship could not be done if cross hangar winds exceeded about 17 knots, all routine servicing and maintenance including engine changes could be done at the mooring out circle. Therefore, the airship need only be docked and undocked for major maintenance for which delays due to unfavorable winds are more easily tolerated.

In addition to the proposed LTA research vehicle, the operations group also discussed the ground handling problems of a large rigid airship. A 15,000,000 cubic foot vehicle was assumed because it is the largest size that could be built in existing construction hangars (Table 3).

Large conventional rigid and metal clad airships might operate primarily in the VTOL mode using static lift and vectored thrust. Take-offs could be made heavy from either mobile or stick-type low masts with vectored thrust providing the extra lift. VTOL landings could be made with the ship light, using vectored thrust to help pull it down. It could be hauled into the mooring cup by the main wire and winch from the mobile or stick-mast.

Two yaw lines could be used to steady the ship's nose from undesirable lateral movement and to prevent the airship from overriding the mast. These lines could be operated by three different systems:

Mobile winches could be similar to those used in the past, but heavier and larger.

At infrequently used sites, a smooth circular path could be prepared for a landing wheel on the aft fin. Deadmen anchored in the ground just inside the path could be used for the yaw line control, with mooring points every 15 degrees along the perimeter of the circle.

Regularly used bases could have a circular railroad track, yaw guy-cars and a railroad rideout car to prevent kiting.

All loading and unloading could be done while the airship is moored out, as could all servicing. In the past, engines were changed and even new gas cells

installed while a rigid airship was moored out (although this admittedly took longer than in the hangar). Any future large rigid airship, except for emergencies, could dock only once a year for major overhaul.

There are problems associated with mooring out any size airship—predominantly icing and high winds. Although dry snow blows off, wet snow, freezing rain or other icing conditions can cause trouble. Several procedures have been tried with varying degrees of success: high pressure fire hoses to wash off snow and ice, passing a line or belt over the top of the airship to pull off the snow and ice or heating the helium in non-rigids. This is an area where further research is needed.

Large rigids have weathered hurricane force winds while moored to a mast and have made flying moors in 45 knot winds. Research is needed, however, on the effectiveness of the various mooring techniques for large rigids in high wind conditions.

For cross country flights overland, a number of ground bases or landing areas would be required at intervals well within normal cruising range of all planned types of airships. In addition to normal airport supplies such as aviation fuels, airship bases should have supplies of helium for emergency "top-ups."

Designated mooring out areas or bases should be reasonably level and smooth with a landing wheel roll-on circle and have an expeditionary or stick mooring mast as described earlier. The areas adjacent to these bases should be reasonably free of tall trees, buildings and electric and telephone lines and poles within the limits of normal airship take-off and landing approaches.

Bases for large rigid airships would be more extensive and elaborate. In addition to the requirements already described, they would need greater approach and take-off clearance, water supplies for ballast replenishment, a suitable mooring mast and stern hold-down facilities. Table 4 summarizes some of the equipment required at airship bases for non-hangar operations.

#### **FLIGHT OPERATIONS**

The paramount consideration of all flight operations must be safety. Airships must be safe, reliable vehicles if they are to serve a useful transportation role. Several

**TABLE 3  
EXISTING LARGE AIRSHIP HANGARS**

Bases	Number of Hangars	Size of Hangars	Maximum Size Airship that can be Housed (cu. ft.)	No. of 1,500,000 cu. ft. Ships that can be Housed
Akron, Ohio (Currently being dismantled)	1	1175' x 325' x 200'	15,000,000	4
Moffett Field, CA	1	1170' x 231' x 124'	14,000,000	4
Moffett Field, CA	2	1000' x 220' x 160'	10,000,000	2 each
Weeksville, NC	1	958' x 258' x 180'	10,000,000	4
Weeksville, NC	1	1000' x 220' x 160'	10,000,000	2
Lakehurst NJ	1	807' x 258' x 172'	7,000,000	3
Lakenurst, NJ	2	1000' x 220' x 160'	10,000,000	2 each
Santa Ana, CA	2	1000' x 220' x 160'	10,000,000	2 each
Tillamook, OR	2	1000' x 220' x 160'	10,000,000	2 each
6 Bases	13	Large Hangars		33 Ships



topics were discussed that have a direct impact on flight safety.

**Weather**—The airship faces the same weather problems as other aircraft—turbulence, icing and high winds. But because of the airship's slow speed and altitude restrictions, these problems are more serious. Long airship journeys may take several days, increasing the need for accurate long term forecasts en route and at the destination.

Prior to take-off, initial flight planning must consider the locations and probable paths of weather systems and associated frontal passages, winds, precipitation, visibility, icing and the like. The flight planner can then select a route and altitude profile that minimizes conditions adverse to the airship and maximizes favorable tail-winds.

Once the flight is underway, the airship crew must be particularly attentive to weather changes. Aside from the more obvious adverse conditions to be avoided, strength and direction of winds must be closely watched because of their impact on performance. Fortunately, weather satellite updates (broad-



cast several times an hour) and reports from other aircraft and ground stations provide adequate information for major on-board flight plan modification.

The quality of modern airborne radar allows early detection of storm centers, heavy precipitation and associated turbulence. Where possible, these areas could be avoided. If the limited speed of the airship prevented circumnavigation, radar could indicate the path of least turbulence.

In summary, weather does present special problems for airship operations. But with modern weather information and on-board electronic equipment, a trained airship crew should be able to attain a high level of safe, regular service.

**Altitude/Payload Management**—In the past, there have been two altitude-related operational problems, both affecting payload. First, because buoyant lift decreases with altitude, an airship on a higher altitude mission could not carry as much payload (or fuel, which would result in a range reduction) as at a lower altitude. Second, as an airship ascends, the gas inside its cells expands. At "pressure height," the cells are full and the airship could not go higher without venting gas—an expensive procedure, especially with helium. Historically, to raise the pressure height, less gas was placed in the cells at the start of the mission, but this also lessened the payload that could be carried. Both of these problems lessen an airship's utility, particularly in mountainous areas.

With modern technology, it may be possible to eliminate altitude problems by controlling gas volume rather than off-loading payload. This could be done by:

Expansion/contraction of the lifting gas mechanically

Liquification/gasification of the lifting gas

Addition/subtraction of heat to the gas, using engine exhaust or the injection of steam

The weight penalty of the equipment needed for the first two approaches seems to be excessive. Although insulation and heat exchange systems may be required for thermal control, this alternative appears most likely to succeed, given today's materials and technology.

**TABLE 4**  
**GROUND EQUIPMENT FOR NON-HANGAR OPERATIONS**

<b>Equipment</b>	<b>Non-Rigid</b>	<b>Rigid</b>
Mules	Proven (ZPG-2/2W and ZPG-3W Operations)	Adaptable
Portable Mast	Proven	Proven (Rigid Operations 1920s-1930s)
Mobile Mast	Proven	Proven
Mobile Fuel and Ballast Equipment	Proven	Proven
Electrical Power Provided Through Mast	Proven	Proven
Gas Replenishment — Mobile or Through Mast	Proven	Proven
Snow and Ice Removal Equipment	Needs Further Research	Needs Further Research
Helicopter Maintenance Vehicle for Upper Envelope and Surface Problems and Ice Removal	Proven	Adaptable
Portable Helium Purification Units	Proven	Adaptable
Railroad Tie-Down	Not Used	Proven

**Air Traffic Control**—The size, speed and maneuverability of airships may dictate airspace allocations. Therefore it will be necessary for airship operations to be compatible with the operation of other aircraft that might occupy the same altitude/route/terminal regime. Compatibility may be achieved by such means as the allocation of special airship routes, terminal areas and altitudes, and air traffic control time and space separation. Either of these methods may well meet strong objection from general aviation, the normal users of low altitude airspace. In addition, alternate bases with associated routings must be available to avoid airspace congestion at primary terminal areas when surface conditions are not conducive to landing. Other than these special requirements due to the airship's large size and low speed, airships should be compatible with the normal ATC system. Trade-offs with other airspace users may induce institutional and/or political problems but no other problems are foreseen.

**Emergency Considerations**—In addition to the normal routine operating procedures which can be developed for a given vehicle and a given mission, there are special procedures used by flight crews in emergency conditions. Such procedures are highly dependent on the vehicle type and mission. However, a few general comments can be made. Careful consideration must be given to the ballast management program in LTA vehicles. The flight crew must be able to cope with adverse ballast conditions which must be easily and rapidly identified. At least one way of rectifying these conditions must be provided (e.g., rapid release of water). Because some LTAs will be large vehicles, adequate crew communications must be provided during emergency conditions, including loss of primary electrical power.

In general, redundancy of vital systems necessary for flight operations alleviates the need for lengthy and complicated emergency procedures, but redundancy is expensive. Therefore, the decision to design redundancy into a vehicle should be made on the basis of trade-off studies of the appropriate costs and benefits, including operational alternatives.

Several areas require special attention:

Body restraining systems

Non-flammable materials

Evacuation procedures

Appropriate crashworthiness

Easy ingress/egress

Past experience from airship operations shows that airship motion occasionally can be violent. However, the size of an airship requires movement of the crew for inspections and maintenance and such mobility is a necessity for passengers on long endurance flights. Long endurance flights will also require beds in addition to seating for crew as well as passengers. Whether some body restraint system will be necessary is unknown.

Existing regulations for flammable materials in airplanes would apply. In addition, new standards would be required for skin fabrics, gas cell materials and the like.

Special attention must be given to the problem of an emergency evacuation. The huge size of the airship envelope in combination with the comparatively diminutive crew and passenger cabin poses a problem unique to airships.

Although existing crashworthiness requirements will have to be met, the low speed, low mass and large size of airships allow a design with high crash attenuation capability, giving additional crew/passenger protection.

The access to gondolas and the interior of the airship could become an operational problem if not properly considered in the configuration of the airship. General requirements have to be analyzed and established as a guide for the design of specific configurations.

In summary, safety procedures must be developed for airships as they have been for ships and airplanes. Special attention must be given to the large size and potentially long duration missions of airships that make them different from airplanes.

**Training Requirements**—Safe operation of the airship must be the paramount consideration at all times. Therefore, today's airship will require training to the same high standards required in aircraft operation.



Some system of certification for the entire crew must be established. Periodic revalidation of proficiency should be an integral part of this certification system. There is every reason to believe that the use of simulators for initial and periodic follow-up training can be employed as a valuable, and probably even essential, training resource.

Safe maintenance practices peculiar to the airship must be established and continually checked through a training and proficiency demonstration program. All areas pertaining to the safe operation of the airship both while airborne and on the ground must become an instinctive part of the habits of all personnel associated with airship maintenance and operation.

**In-Flight Monitoring and Control Systems**—In order to protect the hull's structural integrity during violent maneuvers, past airship designs often limited the amount or rate at which elevator or rudder could be applied. But this also lessened control during periods of severe side or vertical gusts. The best trade-off can be reached by using

- Better structural techniques

- Better materials

- Better automatic flight controls

The latter could use sensors mounted throughout the hull and fin structures to measure the amount of strain caused by control movements or gusts. This could be fed back to the autopilot to reduce the control movement before the strength of any critical part of the structure was exceeded. Therefore, the maximum safe degree of control could always be applied without endangering the safety of the airship. The difficult task is determining what parts of the structure are critical, because minor structural failures which the airship could survive are preferable to crashes or collisions that could have been avoided with more control authority. To increase the safety of airships, improvements in stability and control are necessary, particularly at low speeds (under 20 miles per hour). Lack of control response at these speeds has complicated landing and hovering and also loading and unloading when performed in the open while hovering or at the mast. Better control systems, along with boundary layer control and vectored thrust, could improve this aspect of LTA operations considerably.

### **Technology Working Group**

For specific areas of technology, the problems of designing both conventional and hybrid LTA aircraft were reviewed by subgroups of the Technology Working Group to answer the following questions:

What is the current state of applicable technology?

What improvements over past LTA designs would result from application of current technology to LTA concepts?

Where do gaps exist in technology needed for future designs?

Can we assign priorities for future R&D to fill those gaps?

#### **OVERALL DESIGN/CONFIGURATIONS/MISSION-RELATED PROBLEMS**

This subgroup reviewed a variety of past and present concepts for LTA aircraft, related their performance to missions and then reviewed mission-related technology problems. They also defined various design-related problems for hybrid configurations. The approach was similar to that of the Market Analysis Working Group, but started from a technical perspective rather than from a mission/market perspective.

**Characteristics of Airships**—A wide variety of airship concepts have been explored—and, in some cases, developed—to exploit the unique characteristics of fully and semi-buoyant aircraft. The most significant characteristic of the fully buoyant airship is its ability to lift a load aerostatically without the expenditure of power. However, it pays for this free lift when it tries to move its large volume and size at even moderate speeds. Because of the high drag from the large surface area and displacement of the buoyant envelope, high speeds require very high expenditures of power. Therefore, buoyant lift vehicles are best suited for large loads, low speed and long-endurance missions. Conventional winged aircraft are more suitable for smaller, higher density loads, high speeds and limited endurance missions.

For intermediate missions it may be advantageous to combine buoyant lift with auxiliary lift from wings during cruise or from rotors during hover (propellers during cruise) or perhaps from both wings and rotors. These configurations have given rise to a large number of hybrid LTA concepts. By combining wing, rotor and buoyant lift it may be possible to tailor aircraft design to mission requirements in terms of load size, hover requirements and speed, producing a smaller and more efficient vehicle. For example, conventional airships can perform long endurance loiter missions for days at low speeds, low fuel expenditure and hopefully with low noise and pollution levels. The conventional airship can also be used to lift large loads if an equivalent ballast (perhaps water) can be dropped at the origin and is available at destination. If ballast problems make pure LTA operations impossible then limited buoyant lift might be used to offset the empty weight of V/STOL vehicles. The available wing or rotor lift can then be totally devoted to lifting payload.



Projected advances in both helicopters and conventional airplanes do not appear to provide the large payload capabilities required for certain missions currently envisioned. While no large airships having these large payload capabilities have been built either, LTA appears to have the potential to perform these missions with the proper application of modern technology.

**Classification of LTA Missions**—The following mission areas were examined for possible applications of LTA technology:

- Transportation of heavy, indivisible loads

- Transportation of passengers, containers or break-bulk freight

- Low altitude surveillance

- High altitude surveillance

- Special purpose

The subgroup discussed the movement of large indivisible loads that exceed the capacity of surface transportation systems because of size constraints, interface constraints (over-the-beach) or roadbed capacity. Included were the transportation of large machinery, factory-fabricated structures and specialized equipment for whole-tree logging in rough terrain. The distances involved may be long or short range. Both repeated and one-time missions were considered.

In considering the transportation of passengers, containers or break-bulk freight, the subgroup concentrated on the classical requirement to move people or goods between two points. In this context, LTA will often be competing with other appropriate forms of transportation. Because of its unique characteristics, LTA may be more economical in some cases when total costs are considered. Ranges of interest included very short distances (intracity transports) to very long transoceanic distances.

Low altitude surveillance basically covered the low altitude (less than 20,000 ft.), long endurance and high payload requirement missions. Possible applications include ASW and ocean surveillance operations for the Navy, high resolution geographic mapping, broad

atmospheric/oceanographic sampling or similar activities. Another application would be the relay of electromagnetic signals for communications.

In contrast, high altitude surveillance missions were those using high altitude, line-of-sight sensors where large area coverage is required from a moving or stationary platform. Long endurance is required and payload requirements must be limited, but the cost of the LTA vehicle is relatively low.

Finally, those miscellaneous LTA missions that do not have a significant common denominator were grouped together. Included were such things as sport ballooning and police surveillance of urban areas.

**Matching Concepts to Missions**—The requirements for vehicle performance which are associated with these missions were derived (Table 5). Payload requirements, altitude, endurance, range and control authority vary quite widely, but most missions require speeds below 100 knots and very short takeoff distances. The final step in the analysis was to match some of the vehicle concepts and designs presented at the workshop with the vehicle requirements developed (Table 6). From this analysis, the subgroup decided that there was at least one match between mission and vehicle for each vehicular type and, in some cases, a vehicular type might be appropriate for several missions.

**Special Mission-Related Technology Requirements**—To accommodate instrumentation needed for ASW or geophysical prospecting, special attention may be necessary to minimize interference with the sensors or to insure a favorable environment for them. For example, in geophysical prospecting using sensitive magnetometers, electromagnetic disturbance and vibration must be minimized. This may require the use of non-ferrous, sparkless engines, plastic rather than metallic structures, adequate grounding of all conduction elements, shielding of electrical systems, physical separation of sensors from machinery and extremely low resonant frequency mounting systems if low frequency signals are to be sensed.

For sensors towed in the water, adequate velocity and direction control is needed. Provision must be made to tow heavy systems with large tow forces

**TABLE 5**  
**TYPICAL MISSION PERFORMANCE REQUIREMENTS**

Requirement	Heavy Lift Indivisible Load			Transportation of Passengers and Break-Bulk Freight			Low Altitude Surveillance		High Altitude Surveillance		Special Purpose
	Long Range	Short Range		Long Range	Short Range		Long Range	Short Range	Long Range	Short Range	
Take-Off Capability	V/STOL	VTOL		V/STOL	VTOL		VTOL		VTOL		V/STOL
Speed (knots)	50-100	25-50		50-100	50-100		25-100		0-50		25-100
Range (miles)	100	1-50		500-3,000	1-500		Limited		Limited		50
Endurance	Medium	Short		Medium	Short		Long		Long		Wide Range
Payloads (tons)	200-800	50-400		100-500	50-400		Wide Range		Small		Small
Altitude (feet)	0-5,000	0-5,000		Terrain Dependent	0-5,000		0-20,000		20,000- 80,000		0-3,000
Control Authority	High	High		High	High		Med. High		Low		Wide Range

**TABLE 6**  
**MATCHING CONCEPTS TO MISSIONS**

Concept	Heavy Lift Indivisible Load		Transportation of Passengers and Break-Bulk Freight		Low Altitude Surveillance	High Altitude Surveillance	Special Purpose
	Long Range	Short Range	Long Range	Short Range			
Aerocrane	Possible Application	Primary Application			Possible Application		Possible Applications
Helistat	Primary Application	Possible Application		Possible Application			Possible Applications
Tethered Systems		Primary Application			Primary Application		Possible Applications
Lifting Body	Possible Application		Primary Application	Primary Application	Primary Application		Possible Applications
Conventional Airship	Possible Application	Possible Application	Primary Application	Primary Application	Primary Application		Possible Applications
High Altitude Balloon						Primary Application	



Comfortable, vibration-free spaces for sensor operators will maximize their performance. If on-board acoustic sensing arrays are used, low self noise from machinery and low flow noise in the vicinity of the sensor is necessary.

**Hybrid Design Problems**—Hybrid vehicles pose several problems that need more study. For example, there has been little analysis of the aeroelastic behavior of hybrid configurations that combine rotor/propellers with large semi-rigid or flexible envelopes. Until the dynamic stability coefficients of hybrids are determined, it is impossible to develop automatic stabilization and control systems. In some configurations, large directional thrust rotors are placed around the periphery of the buoyant envelope. The resulting induced flows could exert large aerodynamic forces on the envelope, making hover control and cruise stabilization difficult. Is there one optimal shape for a lifting body LTA configuration or does it change with cruise speed? In configurations that combine wings and buoyant envelopes, the aerodynamic forces on the envelope are unknown where large downwash flows occur on the wings. There may also be a danger of hull flow separa-

tion in crosswinds at low forward speeds and a resulting loss of lift on the relatively small wing.

In general, more needs to be known about distributing large concentrated loads from wings, propellers, thrusters, rotors and large load frames over the very light, low density structure of the hybrid airframe.

### **MATERIALS, STRUCTURES AND MANUFACTURING**

There is no fundamental distinction between buoyant and hybrid airships with regard to materials, structures or manufacturing techniques. Most available or new technologies may be applied to either type of vehicle with differences only in detailed design. Therefore, the discussions of this subgroup apply to both types of airship except where noted.

**Materials**—Progress has been made in the past several years in improving flexible aerostat envelope materials. This pliant materials technology can be applied from present balloon developments to the design of gas cells and envelopes. Among the newer materials are combinations of polyester and Kevlar fibers which offer greatly improved strength and tear resistance. Fabrics capable of transmitting planar shear stresses by virtue of triaxial weaves have also been developed. These newer fabrics using improved fibers display reduced permeability characteristics. However, further development is required in seaming techniques, the effects of other inflation gases and the effect of high super-heat on these new materials.

A wealth of possibilities exists for the use of new materials, such as fiber or laminated composites, metal or otherwise. Their principal value for rigid structures is less in improved strength than in the improved rigidity offered. However, the pay-off for each and every structural material can be fully explored only through an internal configuration design making the maximum use of that material. The combinations and permutations are consequently large and as yet unmapped.

**Manufacturing**—Most of the recent fabrication and manufacturing techniques developed in the aerospace industry can be applied to airship structures, including bonded structures, diffusion bonding and improved

adhesives, to name a few. Special design and handling concepts for minimum gauge, light weight structures may be needed to prevent structural damage during manufacture or in service. Economic fabrication concepts and methods particularly suited to airship construction need to be developed to build low cost airframes.

**Structural Design**—Structural design must synthesize material characteristics with structural concepts. Large capacity, high speed computers are an invaluable tool for this synthesis. At the conceptual design stage, numerous configurations may be evaluated. Once the operational environment is defined, the computer can determine design loading conditions and perform structural analyses of promising configurations. Graphic displays of lines, structural members and plumbing and wiring can be prepared by computer, as well as line drawings and lofting data. Finally, the computer can convert these designs into numerical control tapes for automated die and template cutting. Similar programs have been developed and are currently being used to develop surface and undersea vehicles. In spite of the sophistication in computerized design/analysis, there are deficiencies pertinent, but not unique, to airship applications. More work is needed in non-linear and viscoelastic material and structural behavior, large-deflection analysis, and contact and discontinuity problems. Computer programs have been written specifically to treat these problems. However, they have not been incorporated into large-scale general-purpose programs such as Nastran, Solid Sap or others. These problems are not unique to airship developments. It is not the responsibility of the LTA community alone to solve them. However, the LTA community should promote, cooperate and assist in their solution.

**Loads** - There has been some analysis of the loads on conventional airship configurations for the quasi-static conditions associated with discrete gusts, maneuvering, empennage loads and landing contact velocities. However, the random gust condition has not been explored in the same detail and the condition where multiple gusts act simultaneously in various magnitudes and directions on large bodies has been largely ignored.

The situation becomes increasingly difficult when hybrids are considered. The dynamics associated with the airplane must be combined with those peculiar to the airship. Because these conditions are dynamic, a method of interfacing the buoyant mass and structural response with those of the heavier than air augmented components is needed in order to assess gust alleviation factors. Criteria must be established to determine what hybrid landing contact velocities will be (probably between those of LTA landings and the higher values of HTA).

**Criteria**—LTA load, performance and design criteria need updating and a current standard design manual should be prepared to be used as a reference for the fundamentals of aerostatic design. These documents should include among other topics, chapters on:

Loading—Ground conditions and criteria, flight conditions, including steady state and transient

Design Factors—Specific loads, stresses and limit load factors

Materials—Physical properties, as complete and detailed as possible, of composite metals and fabrics

Gases—Complete physical properties, constants at uniform thermodynamic state, conversion factors for other states (possibly graphics and tables) and standards of gas purity

Fuels—Physical properties of liquid and gaseous fuels

## **AERODYNAMICS, PROPULSION AND PERFORMANCE**

To operate within the present-day transportation system, airships must operate in roles which differ from their traditional applications between the wars. They must operate under weather conditions and within a system of safety restrictions which demand a much higher performance than previously attained. To analyze the overall performance of airships and ways of



improving that performance, this subgroup considered cruising performance, maneuvering performance, performance in conditions of meteorological turbulence and performance in other adverse weather conditions. The subgroup then examined the current state-of-the-art, discussed outstanding problems and made recommendations for further work. Hybrids were reviewed separately.

The investigation of these topics depends upon an integrated program of experimental and analytical work. The subgroup felt that much research may have already been completed, but is not widely known. Therefore participants in the workshop were invited to submit any lists of references associated with airship design work, either from specific airship sources or from associated fields such as underwater vehicle research, wind effects on buildings, etc. A similar listing of available computer programs which could be applied to any aspect of airship performance assessment would be useful.

The wind tunnel work associated with earlier airship development was inhibited by the difficulty of achieving relevant Reynolds numbers. It appears, however, that high pressure tunnels may now be available which would allow meaningful measurements of aerodynamic derivatives and coefficients to be made in appropriate flow regimes. A search should be initiated for information on the existence and availability of such facilities.

Finally, the modern airship must operate in conditions of low altitude turbulence which are inadequately documented. The collection of turbulence spectrum analyses and of information on wind sensing techniques must precede the establishment of an experimental program of wind measurement.

**Cruising Performance**—The general consensus of the subgroup was that buoyant airships, over long stage lengths, should have a cruising speed range of 80 to 100 knots, representing the relatively narrow margin between undesirable sensitivity to adverse winds and excessive fuel consumption. (Proposals for faster ships [200 to 300 kts] were felt to be too specialized for study in this context.) This represents an increase of 20 to 40 knots over earlier designs, with corresponding increases in aerodynamic and structural loading.



and in propulsive power requirements. These lead in turn to a requirement for increased aerodynamic efficiency in cruising flight, which may be achieved by modifying airship geometry or by mechanical means, such as boundary layer control or propulsion system revision.

As far as cruising flight is concerned, it seems unlikely that geometric deviations from the traditional "cigar" form will lead to significant reductions in drag. Further work is necessary on the effects of L/D ratio, on the housing of installations within the hull profile, on the drag of various control surface systems and on the effects of surface texture and rigidity on overall drag coefficients. The flow around a body of revolution in pitched or yawed flight also requires additional investigation.

While the classical form seems most efficient for cruising operation, the increasing importance of maneuverability and control in turbulence at low speeds and altitudes may dictate an alternative geometry. Whether the penalty in cruising flight efficiency will be accepted will generally be decided by the mission for which the airship is designed.

Boundary layer control for airships has been proposed in alternative forms: to reduce wake drag at the tail; to reduce skin friction drag by delay of transition; and to improve control surface performance by local flow control at the hinge break. There is little informa-

tion on wake generation at typical flight values of Reynolds numbers. Therefore, further study is required on the application of boundary layer control in this context, particularly in view of the mechanical and structural problems involved. Effective reduction of skin friction requires suction over almost the whole envelope area. The weight and power requirements would appear to neutralize any aerodynamic advantage which may be achieved. More investigation is required, however, to quantify this qualitative reaction. Control surface blowing is already in use on some aircraft with great effect and its adaptation to airship fins clearly merits further study.

Any revisions to the propulsion system will probably use propellers because they are still the optimum propulsive instrument for the buoyant airship. There is a need for the further development of large, low-speed, low-noise units. Aerodynamic advantages are attainable through the use of wake-immersed propellers and of ducted propellers, but each system involves weight penalties which must be evaluated in the context of the vehicle's mission. The optimum location of tandem propeller units mounted on the airship flanks must be investigated. The interference effects of these propellers on each other and on the airflow over the hull have never been fully analyzed. It appears that cycloidal propellers may have advantages in low-speed maneuvering, though they become extremely inefficient with increasing speed.

A wide power-plant choice is possible if all potential long-term developments are taken into account. A realistic approach must confine itself, however, to the actual and potential performance of units already in use. Because an emergent airship industry will be unable to support a specific program of engine development, such development will be controlled by demand in other industries. Therefore, the lightweight diesel engine probably will not achieve a development rate comparable with that of the gas turbine. The latter becomes more attractive for airship applications as its specific fuel consumption declines. At present, however, the diesel's lower specific fuel consumption is an overwhelming advantage for long range or endurance missions.

The airship would be more readily adaptable to nuclear propulsion than would any heavier than air

vehicle. However, this is a long term prospect and its development will depend on the level of petroleum fuels available in the future.

**Maneuvering**—Maneuver capability in any modern airship will be of more importance at very low speed and altitude than in cruising flight. It is in the former regime that improvements in current performance are particularly necessary. Pressure airship experience has indicated an almost total loss in aerodynamic control effectiveness at speeds below about 17 knots. In other airship designs, the loss of control occurred at lower speeds, but still created operational problems. Significant control at lower speeds can be achieved only by the use of vectored thrust in all three directions. Effective design of such a system requires simulation based on aerodynamic data including second and higher order derivatives. But this information is not available even for traditional geometries. It can only be obtained through wind tunnel experiments over a relevant range of Reynolds numbers.

On certain missions, the low-speed control requirement may require either a total departure from traditional geometries or the application of very large thrust (as in the case of a tilting-rotor helistat). The associated penalty in cruising performance must be reduced to an acceptable level for the mission.

**Meteorological Turbulence**—In cruising flight, the problems of structural loading and controllability under gusting conditions are increased by the size and speed projected for future airships. It is probable that present-day knowledge of gust structure will permit a far more accurate estimate of the conditions airships will be required to meet than has previously been possible.

The necessary improvement in gust resistance may be achieved either by an increase in structural effectiveness (possibly involving a geometry change) or by some form of gust alleviation. Alleviation can be a control function involving moving surfaces or vectored thrust, but alternative possibilities may emerge from the study of flexible structures.

In the low-speed maneuvering and hovering regime, station-keeping becomes more important than structural loading. But the size of the thrust units needed for station keeping may in itself produce significant load-

ing problems. Other problems which require further study include gust sensing techniques, including the use of radar; the dynamic characteristics of an airship in tethered conditions; and airflow in the region of an airship flying close to the ground.

**Hybrid Performance**—A general analysis of hybrid aircraft is inhibited by the wide range of hybrid configurations which have been proposed. All such concepts require further investigation. The degree of analysis depends upon their divergence from configurations for which information already exists. Certain hybrid designs can profit immediately from research on lifting bodies of various forms, including aircraft of low wing loading.

Most of the problems are related to the hybrid's large bulk and low mass. Particular study fields include:

Take-off and landing performance, with particular reference to the vehicle's sensitivity to changes in wind direction, to the rapid decrease of ground effect forces with height and to its slow response

The problems of gust response in cruising flight which in many ways resemble those discussed for the buoyant airship

Interaction between aerostatic, aerodynamic and propulsive forces in maneuvering flight

It seems clear, however, that hybrids offer advantages on certain missions and that further research would be justified.

#### **STABILITY, CONTROL AND HANDLING CHARACTERISTICS**

This subgroup discussed stability, control and handling characteristics to establish the current state-of-the-art, identify problem areas, suggest approaches to solutions and identify new technology required (as opposed to an adaptation of established technologies).

**Equations of Motion**—The rigid body equations of motion for the airship must include the action of air on the hull, a term usually ignored in airplane analysis. A

useful approach is to formulate Kirchoff's equations and determine the energy of the airship and the fluid medium in terms of the airship's motion and geometric shape. Other forces and moments in the equations of motion include body forces such as weight and buoyancy; aerodynamic forces on the hull, empennage and gondola; control forces, both static and aerodynamic, and all the corresponding moments. Additional terms which must be included are gas lag motions and meteorological effects. These include adverse weather conditions (winds, gusts, snow accumulation) as well as changing ambient temperature and pressure.

Some of these inputs can be determined easily. Others pose serious problems. Most difficult to estimate are the aerodynamic drag and lift forces on the hull and their variation with angle of attack. To solve for these terms analytically, skin friction, pressure and induced drag need to be accurately predicted. Aerodynamic lift estimates based on the pressure distribution in real flow, boundary layer, separation point and downstream flow properties must also be accurate. Lack of reliable analytic solutions in airplane studies has led to extensive use of experimental techniques to solve the relevant flow equations. Model experiments will be required for airship analysis as well.

An additional aerodynamic problem is the prediction of rudder and elevator effectiveness because there is little knowledge about flows around the empennage including downwash, sidewash and hull blockage effects.

Once the equations of motion are determined and kinematic effects included, the motion of the airship's center of mass and the airship's attitude response can be predicted. This permits trajectory analyses for linear and curvilinear flight paths as well as estimates of open loop response to the various inputs described.

**Pilot-Airship Dynamic Systems Analysis**—This is a recent technological development which mathematically models the pilot as well as the vehicle and external forces. Conventional automatic control theory is then applied to analyze the behavior of the entire system, including the pilot. The results indicate dynamic incompatibilities and the limitations of both men and vehicle. Although these techniques are now developed and applied to heavier than air vehicles, they were not

available to airship designers of the past.

The ability to model the dynamics of the airship, its pilot and atmospheric disturbances can be used to predict the limits of unaugmented stability and control and the specifications of the automatic control systems required. The need for flight-active cockpit displays, flight-director displays and flight instruments in general can also be specified. Therefore, the adaptation of these techniques to airship design should significantly improve the stability, control and handling characteristics of modern airships.

**Stability Analysis**--With the equations of motion formulated, small perturbations can be analyzed to determine the stability of steady-state flight by expressing the perturbational forces and moments in terms of the corresponding perturbational-state variables and introducing suitable stability deviations. But there are several problems. The first is whether the Bryson expansion can be used for the airship as it is for the airplane. Even if it can, truncation errors must be analyzed. The second problem area is the determination of the derivatives. Analytical predictions of the derivatives with



respect to linear or angular accelerations can be based on potential flow theory. However, those with respect to the linear and angular rates arise from real flow properties and therefore are very difficult to predict analytically. In the past, only derivatives which could be determined experimentally were considered, while the others were ignored. But this often led to only very approximate stability criteria. Clearly, new analytical and numerical procedures or suitable experimental techniques must be developed to determine these real flow derivatives. The sensitivity of the stability criteria to the various stability derivatives can then be studied to determine which derivatives must be known accurately and which ones need only be approximated.

**Structural Flexibility**—Airships, as flexible structures, could resonate and even fail if forced at the appropriate frequencies by turbulence, motion in storms or even active attitude controls. To design around this problem, one must analyze the first few flexible modes of the structure, the operating environment and the interaction of the active attitude control system with the structure. This flexibility analysis, when incorporated into the rigid body equations of motion, would provide a realistic model of airship performance never available in the past.

There are many analytical and experimental problems, however, particularly the modeling of the hull as an elastic structure and the flexibility corrections to the stability derivatives. In addition, the coupling between the lateral and longitudinal motions caused by the effect of the fluid on the airship prevents the decomposition of the stability equations into two separate sets of lateral and longitudinal equations as in airplane analyses. As a result, the stability analysis and the development of stability criteria are greatly complicated.

#### **AUTOMATIC FLIGHT CONTROL SYSTEMS AND COMPUTER CONTROLS MANAGEMENT**

Modern automatic flight control systems were not designed for airship applications and will have to be modified to provide:

Automatic trimming to compensate for variations in mass distribution, center-of-buoyancy shifts,



gas density and temperature changes and atmospheric pressure gradients

Stability augmentation

Altitude and attitude hold functions

Load/gust alleviation

Flight-director displays

Flight-crew station monitoring

Specific flight-path control programming

To perform these functions, the flight control system will need data on airship motion, structural loads, fuel states, atmospheric conditions, gust direction and magnitude, amount and distribution of ballast, buoyant gas state, control and thrust settings, and the like. Although available aircraft instruments can provide much of this information, new sensors must be designed or adapted from other uses to provide the additional data. The resulting flight control and computerized flight management systems will, however, provide greatly improved handling (both in flight and for take-off and landing), and consequently improve overall airship reliability and effectiveness.

**Stability and Control Criteria**—There were many inadequacies in past airship analyses but much is still of use today. However, new criteria must be developed, particularly in the areas of:

Static longitudinal stability

Directional stability

Control power about all axes

Vertical control power, accelerations and decelerations

Control required for trim about all axes

Cross-control ranges of acceptability

Ground proximity phenomena

Limits of automatic control commands

Margins of control available for maneuvering

Dynamic stability about all axes

Speed stability as a function of angle-of-attack  
and flight path angle

Propulsive moments

Both empirical and theoretical studies are needed to provide these criteria for airships. Systems analysis based on sound aerodynamic information can supply the theoretical base, but simulation will be needed to provide empirical data.

**Requirements and Specifications**—There are no general military or commercial requirements or specifications for airships. These should be developed to provide airship designers with much needed guidance.

**Simulation**—Simulation as we know it today was unknown to the airship designers of the past but can be applied to both identify and solve major problem areas. Some uses would be to provide:

Clear identification of the dynamic interface between vehicle, pilot and guidance and control systems

Identification of unsuspected dynamic problems

Aid in training pilots and flight crews

Aid in establishing requirements

Very little new technology is required because airship simulation can take advantage of techniques already developed for airplane simulation.

**Research Projects**—The stability and control subgroup identified several other problem areas where further research is needed:

The violence of turbulence

Techniques other than ballasting and gas venting  
for rapid altitude control

A means of conditioning gas to vary density

Alternatives to pure tail control

---

## COMMENTS

---

After the workshop, draft copies of the report were circulated to all participants for review. The following people provided extensive detailed reviews which were most helpful: Jay S. Brown, Walter P. Maersperger, Norman J. Mayer, William McE. Miller, Jr., Hepburn Walker, Jr., and Donald E. Woodward. Many others responded with comments and suggestions. In most cases, these were easily incorporated directly into the text. In a few cases, however, the comments or recommended changes were significant enough to be documented separately in this section with quotations from participants' letters where appropriate.

### Changes in Text

Numerous editorial changes were made throughout the text to clarify points, expand ideas, etc. These generally were in keeping with the concepts developed at the workshop.

In the Operations Working Group Report, however, a change in emphasis was made. The draft report stressed the need for body restraint systems in flight to



protect passengers and crew from violent unexpected airship motions. This was challenged by several participants, the following comment being the most detailed.

*I know of no instance when a man was thrown off his feet aboard an airship and I have flown 2000 hours*

*In "What About the Airship", Rosendahl states "An Airship has no more need for seat or safety-belts than has the largest steamer"*

*In the summer of 1936, Mr. P. B. Basset of Sperry Gyroscope Co. made a trans-Atlantic flight aboard the Hindenburg during which he ran tests. He concluded that "Normal habits could be continued as though the passengers were still on land"*

*Basset was unable to record any readable acceleration either on take-off or landing—even when flying through turbulent air. The maximum pitch angle in heavy cumulus or thunderstorm weather was found to be from 5 to 10 degrees. On the flight Basset made, the airship stayed on an even keel, plus or minus 2 degrees. Such small angles are not detectable in the passenger quarters. One degree roll was the worst Basset could detect.*

*Goodyear Aircraft published authentic figures showing*

R

the superiority of airships in acceleration loadings. There is practically no shock or vibration as compared to other modes. In an airship, cargo is subjected to 0.5g or less, while airplane maximums can reach 5gs, trucks 8gs and trains 20gs.

These facts and figures apply not only to passenger airships, but also to airships carrying sensitive cargos, or extremely sensitive detection and monitoring equipment.

I think the above facts make body restraining systems unrealistic. Large passenger airships have no need for them and never had. Even small passenger blimps don't need them.

Hepburn Walker, Jr.

## General Comments

The following comments are addressed to the overall emphasis and scope of the report. Mr. Maersperger's comments, while not representing the views of most of those who attended the workshop, are probably held by many in the aeronautical community as a whole.

The emphasis of the report appears to be stated in the reverse. The report lauds the usefulness of buoyant aircraft if only some way can be found to make them economic. The emphasis should be that buoyant aircraft have proved to be disappointing, except (1) for advertising by their manufacturer, (2) by the Navy for anti-submarine work in wartime only, and (3) by one lumbering firm as a substitute for road building.

The report should emphasize that all the commercial success indicated by the Zeppelin Company operations in the late 1920s and 30s (which led to an American-German joint venture being capitalized) has no relationship to the safety requirements that would today prohibit such operations. As for WWII naval blimp anti-submarine operations, touted as hugely successful, no public report appears to be available as to why the US Navy discontinued them, despite the greatest threat from submarines from the most vicious and most implacable enemy the free world has ever known. Something is strangely missing from the public record as to the liabilities of blimp operations. The report should state that most of the surveillance missions once considered ideal for the employment of blimps are now being performed by satellites. Thus, based on past performance, the

record of buoyant aircraft was so discouraging that it led to their abandonment.

The question then turns to whether new materials, power plants or computational methods could provide sufficient improvement to change the picture, to make them acceptably safe and economic. Again, the report should emphasize that the answer is "No". The inherent bulk, low power, low speed, altitude limitations and poor controllability are such great deficiencies, none could be improved sufficiently to reverse the findings. In particular, the ground handling problems, so expensive and destructive of Zeppelin operations in the past, have had no improvement whatever in the 37 years since the last commercial Zeppelin flew. The suggestion of the Enthusiasts, to ignore this fundamental problem and to build vastly larger zeppelins than ever before, borders on complete irresponsibility.

In view of the demonstrated utter impracticality of buoyant aircraft for commercial usage (and leaving military usage out of the discussion from this point forward) the report must explain the apparent commercial interest as revealed in a few of the technical papers. The answer is that these papers each considered a very special application.

The report should note that each of these possible applications requires a different form of buoyant aircraft: zeppelin, transporter, captive balloon, and the Navy a fourth type, the blimp. It follows that no one study can lead to a solution. Nor can one R&D type aircraft development explore more than one possible application. Each study or exploratory building program will be unique to itself. There can be little carryover possible in structure, propulsion, flight operations, etc. from one application to another, as each is different in materials, structure, propulsion, control, speed, range, altitude and method of carrying the load.

The one successful application, the logging balloon, is a triumph of risk capital investment and the capitalistic system. It points the way to other possible successful applications. The best course for government is to follow a tax policy favorable to corporations for investing in risk enterprises.

The above is the gist of what the report should emphasize. The remainder is excellent back up, with but one remaining fault. The report is couched in an academic synthesis of what transpired in the paper presentations and the workshop sessions. It is suggested that not even a graduate mechanical engineering student could under-

R

stand just what the inherent limitations of buoyant aircraft are from a reading of the workshop report, unless he majored in buoyant aircraft design and operations. Somehow, these must be explained in the workshop report. Otherwise, the Congress and the American people may never understand the reasons why only very discrete applications and expert engineering and operations can ever lead to success in this most difficult field

Walter P. Maersperger

The following comments by Mr. Miller point out the general lack of knowledge of hybrids and their problems during the working sessions. This was not necessarily a fault of the workshop itself, but rather a result of the general lack of operating experience and analysis of hybrid aircraft systems. This is clearly an area where more research is required.

Taken as a whole, the working session participants were comfortable with classical airship matters. Many had a long familiarity with these concepts, but understandably few had any background in hybrids.

This lack of background plus the diversity in concepts and varying depth of the papers presented at Monterey produced a type of agnosticism on the whole subject in some working sessions. (Operations totally ignored hybrids.)

The Report has suffered from this and it is insufficient to rely on the Proceedings to bring out various views. There should be appropriate recognition of the two years of work by Dewey Havill which, though preliminary, did provide a clear economic case for hybrid lifting-body airships. Our own engineering and flight tests with an optimized hull decisively advanced lifting-body airships beyond the paper-hybrid conceptual level. What false egalitarianism removes this from the assessment of hybrids?

Aereon has spent over \$500,000 in research and development through manned flight, which no other hybrid has achieved. Havill's studies of lifting-body airships took at least two man-years. This is more knowledge and experience than is indicated by the statement "However, even less is known about hybrids." The fact is that the economics of conventional airships are very much in question. (Why else have they been so little regarded?) On the other hand, it is the technology of hybrids which needs exploration given the apparent economic potential which is indicated. Research is needed to verify the assumed structure weight growth laws and to analyze, predict and test

stability and control.

*In short, both technology and market research should proceed concurrently.*

*William McF. Miller, Jr.*

## **Comments on the Policy Working Group Report**

The following represent the two predominant views of how LTA development should proceed. The majority of workshop participants would probably endorse Mr. Brown's approach, although a significant and vocal minority would probably feel that action, not studies, are needed and needed now.

*The policy group statement should emphasize the need to begin a government sponsored flight research program utilizing LTA vehicles which incorporate the latest equipment, materials, processes and design procedures to provide an adequate data base for the many, needed analytical studies in order to reduce the technical and economic uncertainties of these studies. Without the real data base, the credibility of the paper studies will be impaired. The vehicles used should represent, to the extent economics permits, the range of vehicle types which appear to have real merit and the vehicles should be large enough to minimize scale effects and the problems of data extrapolation to the full-sized vehicles. Included here would be rigid and non-rigid, fully-buoyant airships and fixed and rotary wing hybrids. The criteria for these flight research vehicles should be based on broad, market-research studies which define the real needs for the ultimate vehicles. Because such a study should be all-encompassing, it should be conducted under the auspices of an appropriate government agency.*

*Stephen J. Keating, Jr.*

*The policy statement should stress that a market analysis is needed to determine whether there is any sense in pursuing LTA further. The Economics Group recommended this. Technology noted this too, pointing out that they could not design any vehicle until they had a market area and cost envelope within which to work. The Market Analysis*



group laid some guidelines for the effort.

I would like to suggest the following strategy for LTA development:

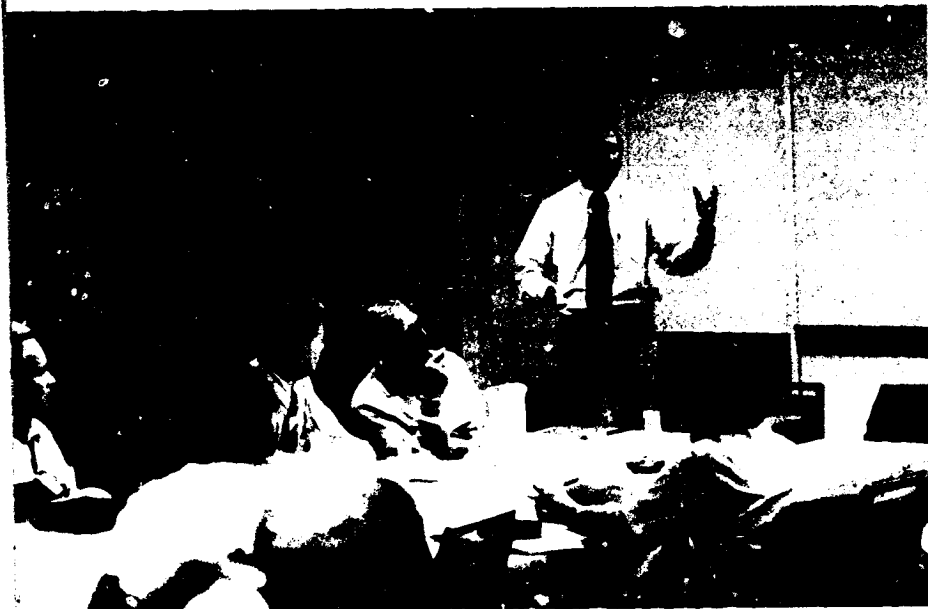
- a. Perform market analyses of potential LTA applications.
- b. Identify unique or "best" (best being obvious areas where an LTA vehicle could outperform any other existing vehicle) roles for LTA applications.
- c. Further identify the most simple applications to implement in terms of least technological development required, estimated least costs, etc—that is, things that are immediately "do-able" now given the state-of-the-art involved.
- d. Proceed with the required economic and technological studies and then decide whether to develop the LTA vehicles for the purposes identified or not.

Once dedicated LTA vehicles are performing cost-effective services, some practical man will adapt one for another purpose and complain about the lack of a vehicle designed for his purposes. Then you have another new market. Additionally, this strategy would involve promoting existing LTA applications to find other services they could now perform. Specifically what else could the tethered logging and communications balloons do now? What could the Goodyear blimp do? If LTA is to fly, it must be sold and every conferee is a potential salesman. Tethered balloon systems will eventually help sell aerocranes, aerocranes could sell other hybrids or fully buoyant types for missions they could do better. Essentially we need to help each other.

Jay S. Brown

### **Comment on the Economics Working Group Report**

Mr. Woodward made the following comment on the Economics Group's lack of ability to get a handle on airship costs.



*I am not convinced that all possible use has been made of the traditional aircraft industry rule of guesstimating "Dollars per pound empty, adjusted by prevailing wages." Published data on Akron/Macon actual costs, compared with Goodyear quotes for the 3 million cubic foot training rigid of 1938, the 10 million cubic foot Navy cargo rigid program of 1944, and the 10 million cubic foot Merchant Airship proposals of 1946-48, fit this "rule" quite closely. Projected to 1974, without allowing anything for the very considerable increases in overhead rates since WWII, these historical data suggest a cost per pound of empty weight of somewhat over \$100 for Zeppelin-type airships with hand-riveted joints, which is no doubt the most expensive kind of airship which could be built. (This would be for follow-on airships of a series. Goodyear would seem to have estimated prototype ships, including design and drawings, at twice this cost.) On this admittedly shaky basis, detail studies ought to be able to estimate the relative reductions attainable with different joining methods, different girder designs, use of metalclad rather than Zeppelin structure, etc.*

*Donald E. Woodward*

**REPRODUCIBILITY OF THE  
ORIGINAL PAGE IS POOR**

## **Comment on the Operations Working Group Report**

The following quote from Mr. Woodward's extensive letter completes the major comments on the report.

*The discussion of performing all servicing while a large rigid airship is moored out, so it would only dock once a year for major overhaul, is so oversimplified as to be misleading. While engines have been changed at the mast, even for large rigids, the job is considerably quicker and easier in the shed. TBOs, of, e.g., the high speed Diesels which are often suggested for airships tend to run around 500 800 hours in naval patrol boat service, which is but a fraction of the projected desired annual utilization of the big airships. With a number of engines per airship, the extra out-of-service time for engine changes at the mast, instead of in the hangar, would be of economic significance. Gas cell changes were normally a part of major maintenance, and required removing the shear wires from one or more panels at the bottom of each bay being changed. Doing this at a mast would be strictly an emergency measure, as the ship would be prevented from flying by both structural and buoyancy deficiencies, and must therefore endure whatever weather occurs at the mast, in a less-than-perfect material condition. It would also appear difficult to avoid losing most or all of the helium in the replaced cell without the overhead deflation piping used in hangars. This consideration would also affect helium purging and/or purification operations, although perhaps to a lesser degree.*

Donald E. Woodward

---

## SUMMARY AND ANALYSIS

---

LTA does offer great potential as transport for both civilian and military applications. Although further research is needed to develop advanced LTA vehicles, the technology is in hand to build and operate modern airships today that would be considerably better than those of the past. The key question is whether these modern airships make sense economically.

It is clear that unmanned LTA lifting devices can be produced and operated economically. But the viability of large manned airships is still uncertain. Because there is no real economic data on costs and performance, estimates of airship economics vary widely. Ultimately, an airship must be built and operated to provide hard data.

But before actual development and construction, rigorous market analysis should be performed to determine what groups would use airships under what conditions. By looking at potential airship applications and determining what cost and performance characteristics are needed for airships either to capture roles now performed by other vehicles or to carve out new, unique applications, design specification can be evolved. Designers can then estimate whether or not airships can be built to meet these specifications. If not, there is no need to build operational vehicles.

Yet not every new concept or invention comes out of market analysis. Therefore, market research should be paralleled by continued technical investigation of new systems, subsystems and fundamentals which could lead to new or improved concepts. These, in turn, could lead to new markets and missions.

Because of the potential national benefits of airships for both civilian and military applications, the federal government as well as private industry should fund this market analysis as well as be ready to support devel-

opment, if the market analysis is positive). The basic market analysis would be relatively inexpensive, probably less than one million dollars, and is the next logical step in developing a modern airship system.



## ATTENDEES

Henry R. Ahlgrim  
1640-1/2 Francisco St.  
Berkeley, Ca. 94703  
(415) 848-6772

H. Julian Allen  
Consultant  
769 Melville Ave.  
Palo Alto, Ca. 94301  
(415) 321-9187

R. S. Andrews  
RAdm., USN (Ret.)  
315 Alberta Way  
Hillsborough, Ca. 94010  
(415) 343-2850

Mark D. Ardema  
Aerospace Engineer  
NASA Ames Research Center  
MS-202-7  
Moffett Field, Ca. 94035  
(415) 965-5887

Lisa Aschmann  
321 National St.  
Santa Cruz, Ca. 92507  
(408) 427-1258

Robert L. Ashford  
Capt., USN (Ret.)  
Advisory Engineer, Electronics  
Warfare Dept.  
Westinghouse Defense and  
Electronics Systems Center  
P O. Box 746  
Baltimore-Washington International  
Airport  
Baltimore, Md. 21203  
(301) 765-6752

Raymond A. Ausrotas  
Assoc. Director, Flight  
Transportation Laboratory  
Massachusetts Institute of  
Technology  
Room 33-412  
Cambridge, Ma. 02139  
(617) 253-7574

Jack T. Avery  
Systems Analyst  
Naval Undersea Center  
Code 14  
San Diego, Ca. 92132  
(714) 225-6653

David B. Bailey  
Aerospace Engineer  
Naval Air Development Center  
Code 3015-1  
Warminster, Pa. 18974  
(215) 672-9000, ext. 2221/2326

R S Bailey  
Dept. Manager/SETL  
TRW Systems  
R5/2261  
1 Space Park  
Redondo Beach, Ca. 90278  
(213) 535-2086

Jacqueline Balaskovic  
Engineer  
C N R S  
91-370-Verrieres le Busson  
B P 11  
France  
920 10-60

Pierre Balaskovic  
Engineer, Project Manager  
O.N.E.R.A.  
29 Ave. du Gen. Leclerc  
92-Chatillon sous Bagneux  
France  
253-50-80

George J. Beier  
Economist, Transportation and  
Urban Projects Dept.  
International Bank for  
Reconstruction and Development  
1818 H St., N.W.  
Washington, D.C. 20433  
(202) 477-5334

N. T. Bennett  
Cdr., British Navy Staff  
P.O. Box 4855  
Cleveland Park Station  
Washington, D.C. 20008  
(703) 920-8950

Fred T. Berry  
Quest Research Corp.  
1315 Stone Meadow Way  
Vienna, Va. 22180  
(703) 790-5800, ext. 225

C. J. Berthe, Jr.  
Cdr., Special Asst. (Air Programs)  
Office of the Asst. Secty of the  
Navy, R&D  
Room 4875  
Pentagon  
Washington, D.C. 20350  
(202) 695-6913

Frederick Bloetscher  
Systems Engineer  
Goodyear Aerospace  
Dept. 915G  
1210 Massillon Rd.  
Akron, Oh. 44315  
(216) 794-7446

M. T. Bowe  
San Jose Mercury News  
705 Ridder Park Dr.  
San Jose, Ca. 95131  
(408) 289-5000

Daniel E. Brady  
Airship Rigger, USN (Ret.)  
6695 Hazel Green Rd., N.E.  
Salem, Oregon 97303  
(503) 393-5617

John W. Brainard  
Special Agent, Investigative Service  
Dept. of Defense  
Naval Postgraduate School  
P.O. Box 8687  
Monterey, Ca. 93940  
(408) 373-3047

John J. Branson, Jr.  
Asst. Professor, Aviation Safety  
Naval Postgraduate School  
Code 034  
Monterey, Ca. 93940  
(408) 646-2582

Jay S. Brown  
Director, Program Development  
Division  
Military Sealift Command  
Dept. of the Navy  
M-63  
Washington, D.C. 20390  
(202) 282-2824

Joe H. Brown, Jr.  
Manager, Flight Systems Tech.  
Section  
Battelle Columbus Laboratories  
505 King Ave.  
Columbus, Oh. 43201  
(614) 299-3151, ext. 2591

Paul M. Browne  
TRW Systems  
R5/2170  
1 Space Park  
Redondo Beach, Ca. 90278  
(213) 535-1772

Robert W. Buchheim  
Deputy Asst. Director, NWT Bureau  
Arms Control & Disarmament  
Agency  
320 21st St., N.W.  
Washington, D.C. 20451  
(202) 632-2069

Ben Cagle  
Office of Naval Research  
1030 E. Green St.  
Pasadena, Ca. 91106  
(213) 795-5971

D. E. Calkins  
177 Wilson, #68  
Albany, Ca. 94710  
(504) 574-6435

Bernard H. Carson  
Professor, Aerospace Engineering  
U.S. Naval Academy  
Annapolis, Md. 21402  
(301) 267-3285

Emilio Castanon-Pasquel  
Director, Dept. of Social and  
Institutional Development  
Organization of American States  
1725 I St., N.W., Room 905  
Washington, D.C. 20006  
(202) 381-8541

George M. Christner  
Vice President, Technical Services  
Megalifter Co.  
P.O. Drawer J  
Goleta, Ca. 93017  
(805) 964-6573

Frank M. Clark  
President  
Megalifter Co.  
P.O. Drawer J  
Goleta, Ca. 93017  
(805) 964-6573, 964-3773

William A. Clugston  
USN (Ret.)  
19200 S. Marin St.  
Gardena, Ca. 90248

Walter V. Collins  
Noise Abatement Officer  
Los Angeles Dept. of Airports  
1 World Way  
Los Angeles, Ca. 90009  
(213) 646-2242

Andrew J. Compton  
Lt. Cdr., USN  
Naval Undersea Center  
Code 1511  
San Diego, Ca. 92132  
(714) 225-7595

Stephen Coughlin  
Research Officer, Centre for  
Transport Studies  
Cranfield Institute of Technology  
Cranfield, Bedford  
England  
Bedford 750111, ext. 525

Arthur G. Crimmins  
Manager, Aerocrane Program  
All American Engineering Co.  
P.O. Box 1247  
801 S. Madison St.  
Wilmington, De. 19899  
(302) 654-6131

Richard F. Cross, III  
Special Asst. to the Administrator  
Federal Aviation Administration  
AOA-10  
800 Independence Ave., S.W.  
Washington, D.C. 20591  
(202) 426-3375

Edward Cullen  
274 Church St.  
Toronto, Ontario  
Canada  
(705) 364-3530

John Curry  
Staff Engineer  
United Airlines  
Code SFDEG  
San Francisco International Airport  
San Francisco, Ca. 94128



Leonardo A. DaSilva  
Chief, Industry and Infrastructure  
Section  
Interamerican Development Bank  
801 17th St., N.W.  
Washington, D.C. 20577  
(202) 362-5071

Arthur C. Davenport  
President  
Dynapods, Inc.  
P.O. Box 2568  
New Orleans, La. 70176  
(504) 899-8086

Frank Dellamura  
Engineer  
Grumman Aerospace Corp.  
Bethpage, N.Y. 11714  
(516) 575-1294

D. H. Dennis  
Deputy Chief, Systems Studies  
Division  
NASA Ames Research Center  
Moffett Field, Ca. 94035  
(415) 965-5358

Donald B. Doolittle  
Director, Aerocrane Program  
All American Engineering Co.  
P.O. Box 1247  
801 S. Madison St.  
Wilmington, De. 19899  
(302) 654-6131

L. L. Douglas  
Asst. to the President  
Boeing-Vertol Co  
P31-09  
P.O. Box 16858  
Philadelphia, Pa. 19142  
(215) 522-2220

Hubert M. Drake  
Chief, Aeronautics Division  
NASA Ames Research Center  
MS 227-4  
Moffett Field, Ca. 94035  
(415) 965-5851

John L. Duncan  
Professor, Mechanical Engineering  
McMaster University  
Hamilton, Ontario L8S 4L7  
Canada  
(416) 525-9140, ext. 4294

Richard M. Dunlap  
Director for Plans and Analysis  
Naval Underwater Systems Center  
Newport, R.I. 02840  
(401) 841-3813

George P. Durney  
Program Manager, Aerostats  
ILC Dover  
350 Pear St.  
Dover, De. 19901  
(302) 674-4020, ext. 345

D. S. Elbourne  
Divisional Director  
John Laing Construction Ltd.  
Page Street  
London NW7 2ER  
England

Harold C. Engen  
Design Engineer  
MITRE Corp.  
MS-08255  
Box 708  
Bedford, Ma. 01730  
(617) 271-2756

L. M. Epps  
Asst. Director, Advanced Civil  
Systems  
Grumman Aerospace Corp  
Plant #5, Dept. 664  
Bethpage, N.Y. 11714  
(516) 575-1294

Michael O. Evanick  
Field Representative  
Office of Naval Research  
Federal Bldg  
Ft. Snelling, Mn. 55111  
(612) 725-4663

R

John S. Ewins  
Research and Development  
Canadian National Railways  
2 Westbourne Ave.  
Acton, London W3 6JL  
England  
01-992 2443

Joseph E. Fielding  
Lt. Col., Canadian Defense Liaison  
Staff  
Senior Staff Officer, Aeronautical  
Engineering  
2450 Massachusetts Ave. N.W.  
Washington, D.C. 20008  
(202) 483-5505, ext. 296

F. Hamilton Fish, Jr.  
Christina Laboratory  
E.I. duPont de Nemours & Co., Inc.  
Wilmington, De. 19898  
(302) 774-0714

Louis J. Free  
Special Assistant (Planning)  
New London Laboratory  
Naval Underwater Systems Center  
New London, Ct. 06320  
(203) 442-0771, ext. 2454

William R. Fromme  
Policy Analyst, Office of Aviation  
Policy  
Federal Aviation Administration  
AVP-210  
Washington, D.C. 20591  
(202) 426-3420

John D. Furber, Jr.  
286 Crescent  
San Francisco, Ca. 94110

Roy P. Gibbens  
Product Design Engineer  
Taylor Instrument Co  
Glen Bridge Rd  
Arden, N.C. 28704  
(704) 684-8111

Lou Gilfix  
Economist  
Dept. of Transportation  
TPI-9  
Trans Point Bldg.  
Washington, D.C. 20590  
(202) 426-4203

Michael Goodman  
Management Consultant  
929 Massachusetts Ave., Apt. 10F  
Cambridge, Ma. 02139  
(617) 661-0182

Stuart A. Gordon  
Consultant  
492 Townshend St.  
St. Lambert, Quebec  
Canada  
(514) 672-2979

Lawrence P. Greene  
Assistant for Aeronautical R&D  
Dept. of Transportation  
TST-7  
400 7th St., S.W.  
Washington, D.C. 20590  
(202) 426-4516

Bernard Grochal  
Aerospace Engineer, Airframe  
Branch Engineering and  
Manufacturing Division  
Federal Aviation Administration  
AFS/120  
Washington, D.C. 20591  
(202) 486-8382

L. R. "Mike" Hackney  
Technical Task Force on Lighter  
Than Air  
Southern California Aviation  
Council, Inc.  
c/o World Air Show  
P.O. Box 1976  
Pasadena, Ca. 91109  
(213) 795-8150

Norman D. Ham  
Professor, Aeronautics and  
Astronautics  
Massachusetts Institute of  
Technology  
Room 33-410  
Cambridge, Ma. 02139  
(617) 253-2423

David Hanchet  
Project Officer  
Transportation Development Agency  
2085 Union Ave.  
Montreal, Quebec H3A 2C3  
Canada  
(514) 283-7815

George S. Handler  
Consultant  
Naval Weapons Center  
Code 35034  
China Lake, Ca. 93555  
(714) 939-3993

Edwin E. Hanson  
Cdr., USN  
Office of the Chief of Naval  
Operations  
Dept. of the Navy  
OP-961C31  
Washington, D.C. 20350  
(202) 697-0059

Michael Harper  
Aerospace Engineer  
NASA Ames Research Center  
MS-202-7  
Moffett Field, Ca. 94035  
(415) 965-5887

Jack P. Harris  
Pinkerton Computer Consultants  
65 W Street Rd  
Warminster, Pa 18974  
(215) 656-3100

Robert Harthoorn  
Gen. Manager, Equipment Control  
A.C.L.  
Holland America Line  
Postbus 977  
Rotterdam  
The Netherlands  
010-392370

C. Dewey Havill  
NASA (Ret.)  
22330 Holt Ave.  
Los Altos, Ca. 94022  
(415) 967-4858

David C. Hazen  
Professor, Aeronautical Engineering  
Princeton University  
Engineering Quadrangle  
Princeton, N.J. 08540  
(609) 624-5532

Stewart Herod  
Advertising Director  
All Canadian Blimp Co.  
607 Young St., Suite 306  
Toronto, Ontario  
Canada  
(416) 878-5962

Heather Campbell Hinton  
Asst. Political Scientist, Economics  
Dept.  
Rand Corp.  
1700 Main St  
Santa Monica, Ca. 90406  
(213) 393-0411, ext. 439

John R. Hooper, Jr.  
Asst. Program Manager, Air  
Systems  
Naval Undersea Center  
San Diego, Ca. 92132  
(714) 225-6377

R. L. Hotaling  
President  
Hotaling Corp.  
P.O. Box 28816  
Sandy Spring, Ga. 30328  
(404) 252-4240

R  
Ralph Huston  
Engineering  
Goodyear Aerospace  
Dept. 461D  
1210 Massillon Rd.  
Akron, Oh. 44315  
(216) 794-4773

Lee Jamison  
Marketing Manager, LTA Systems  
Sheldahl, Inc.  
North Highway Three  
Northfield, Mn. 55057  
(507) 645-5633

Bruno Joner  
Project Engineer  
Boeing-Vertol Co.  
P O. Box 16858  
Philadelphia, Pa. 19142  
(215) 522-3201

S. P. Jones  
Manager, Aerostat Systems  
TCOM Corp  
P O. Box 1797  
Baltimore, Md. 21203

William A. Jones  
Maj., USA  
Operations Research Analyst,  
Military Traffic Management  
Command  
Transportation Engineering Agency  
P O. Box 6276  
12388 Warwick Blvd  
Newport News, Va. 23606  
(804) 878-2866

Gerald G. Kayten  
Director, Study and Analysis Office  
NASA Headquarters  
Code RX  
600 Independence Ave.  
Washington, D.C. 20546  
(202) 755-4225

Stephen J. Keating, Jr.  
Program Manager, Airborne Heavy  
Lift Transport Systems  
Combustion Engineering, Inc.  
1000 Prospect Hill Rd.  
Windsor, Ct. 06095  
(203) 688-1911, ext. 620

Arthur O. Korn  
Aerospace Engineer  
Air Force Cambridge Research  
Laboratory  
L. G. Hanscom Field  
Bedford, Ma. 01730  
(617) 861-3474

Milan J. Krasnican  
Aerospace Technologist  
NASA Headquarters  
Code RX  
600 Independence Ave.  
Washington, D.C. 20546  
(202) 755-3227

R. H. Krida  
Acting Director, Advanced Concepts  
Naval Air Systems Command  
AIR-03P3  
Washington, D.C. 20361  
(202) 692-7393

E. C. Laming  
Mechanical Engineering Dept  
Imperial College  
South Kensington, London SW7  
England  
(015) 895111

Thomas G. Lang  
Mechanical Engineer  
Naval Undersea Center  
Code 608  
San Diego, Ca. 92132  
(614) 225-6495

William A. Langer, Jr.  
Director, Air Vehicle Tech. Dept  
Naval Air Development Center  
Warminster, Pa. 18974  
(215) 627-0000 ext. 2303, 2891

Harold M. Larsen  
Head, Concept Development Branch  
Naval Weapons Center  
Code 4511  
China Lake, Ca. 93555  
(714) 939-7412/3

Hal Lawrence  
President  
Hal Lawrence, Inc.  
Town & Country Village  
Palo Alto, Ca. 94025  
(415) 326-2000

Jane Lawson  
Economist  
Dept. of Transportation  
400 7th St., S.W., Room 10305  
Washington, D.C. 20590  
(202) 426-4436

Donald M. Layton  
Assoc. Professor, Aeronautics  
Naval Postgraduate School  
Code 57  
Monterey, Ca. 93940  
(408) 646-2997

Leslie K. Lear  
Director, Government Marketing  
ILC Dover  
350 Pear St.  
Dover, De. 19901  
(302) 674-4020, ext. 335

Richard Leavitt, Jr.  
Lt. Cdr., USN  
Surface Systems Technical Officer  
Naval Undersea Center  
569 Berland Way  
Chula Vista, Ca. 92010  
(714) 225-7595

Thomas H. Lee  
Vice President, Scientific Systems  
Pinkerton Computer Consultants  
65 W Street Rd  
Warminster, Pa. 18974  
(215) 656-3100

Richard Leger  
Reporter  
Wall Street Journal  
220 Battery St.  
San Francisco, Ca. 94941  
(415) 433-3200

Ben B. Levitt  
Director, Tactical Systems Division  
Operations Research, Inc.  
1400 Spring St.  
Silver Spring, Md. 20910  
(301) 588-6180

Stephen E. Lewis  
Attorney  
Schiff, Hardin & Waite  
7200 Sears Tower  
233 S. Wacker Dr.  
Chicago, Il. 60606  
(313) 876-1000

Jack Liebster  
Regional Planner  
Association of Monterey Bay Area  
Governments  
441 High St.  
Santa Cruz, Ca. 95060  
(408) 373-8477

I. Linder  
RAdm., USN  
Superintendent  
Naval Postgraduate School  
Monterey, Ca. 93940  
(408) 646-2511

Oscar E. Loeser  
Cdr., USN (Ret.)  
4849 55th St  
San Diego, Ca. 92115  
(714) 582-9084

Charles Lombard  
Minority Counsel  
Senate Aeronautics & Space  
Sciences Committee  
Rosen Bldg., Suite 231  
Washington, D.C. 20510  
(202) 225-6477

Ronald L. Luebke  
Director  
Turbo Machines, Inc.  
P.O. Box 2157  
Mission Viejo, Ca. 92675  
(714) 586-2000

Keith McElwain  
Lt. Col., USA  
Technical Director, DOD  
Containers Systems Division  
Office  
Commander, Army Materiel  
Command  
AMC-PM-CS, Attn. McElwain  
5001 Eisenhower Blvd.  
Alexandria, Va. 22333  
(202) 274-8804

Dal V. Maddalon  
Aerospace Engineer  
NASA Langley Research Center  
Hampton, Va. 23665  
(804) 827-3838

Joel Maeks  
Technical Staff  
MITRE Corp.  
MS-B 260  
P.O. Box 208  
Bedford, Ma. 01730  
(617) 271-4979

Walter P. Maersperger  
Lt. Col., USAF (Ret.)  
2 Forest Knoll Rd.  
Monterey, Ca. 93940  
(408) 625-2026

Fendall Marbury  
Naval Architect  
Ketrion, Inc.  
1400 Wilson Blvd  
Arlington, Va. 22209  
(703) 527-4200

Henry S. Marcus  
Asst. Professor, Marine Systems  
Center for Transportation Studies  
Massachusetts Institute of  
Technology  
Room 5-207  
Cambridge, Ma. 02139  
(617) 253-5151

Walter F. Martin  
Scientific Officer, Project Skyhook  
Office of Naval Research  
800 N. Quincy St.  
Arlington, Va. 22217  
(202) 692-4218

Alfred C. Mascy  
LTA Workshop General Chairman  
Aerospace Engineer  
NASA Ames Research Center  
MS-202-7  
Moffett Field, Ca. 94035  
(415) 965-5887

Lynwood May  
Physicist  
Naval Postgraduate School  
13488 Paseo Terrano  
Salinas, Ca. 93901  
(408) 484-1873

Norman J. Mayer  
Program Manager, Advanced  
Concepts and Composite  
Materials  
NASA Headquarters  
Code RWS  
600 Independence Ave., S.W.  
Washington, D.C. 20546  
(202) 755-3280

Carmen J. Mazza  
Head, Flight Dynamics Branch  
Naval Air Development Center  
Code 3015  
Allentown, Pa. 18974  
(215) 672-9000, ext. 2326

Leonard E. Mellberg  
Research Physicist  
Naval Underwater Systems Center  
PA 2  
Newport, R.I. 02840  
(401) 841-2660

James Menke  
Manager, Tethered Aerostat Systems  
Sheldahl, Inc.  
North Highway Three  
Northfield, Mn. 55057  
(507) 645-5633

Marvin Miles  
Aerospace Writer  
L. A. Times  
202 W St.  
Los Angeles, Ca. 90053  
(213) 625-2345

Edward Miller  
Aeronautical Engineer  
Air Force Systems Command  
FTD-FDXS  
Wright-Patterson Air Force Base,  
Oh. 45433  
(513) 257-3342

Stan Miller  
Public Affairs Officer  
NASA Ames Research Center  
MS-204-12  
Moffett Field, Ca. 94035  
(415) 965-5091

William McE. Miller, Jr.  
President and Treasurer  
Aereon Corp  
1 Palmer Square  
Princeton, N.J. 08540  
(609) 921-2131

A. G. Moncrieff  
Technical Controller  
Consolidated Gold Fields, Ltd  
49, Moorgate  
London EC2R 6BQ  
England  
01-606-1020

C. Frank Mosner  
President  
Mosher Balloon Systems, Inc.  
2026 Westwood Lane  
Eugene, Or. 97401  
(503) 343-9021

Edwin Mowforth  
Design Director, Airfloat Transport  
Ltd.  
Lecturer, Mechanical Engineering  
University of Surrey  
Guildford, Surrey  
England  
Guildford 71281, ext. 371

Fred R. Nebiker  
Manager, Aeromechanical Systems  
Goodyear Aerospace  
Dept. 915G  
1210 Massillon Rd.  
Akron, Oh. 44315  
(216) 794-2294

Thomas F. Neu  
Aerospace Engineer  
Naval Air Development Center  
Code 3033  
Warminster, Pa. 18974  
(215) 672-9000, ext. 2866

Richard D. Neumann  
Chairman, Technical Task Force on  
Lighter Than Air  
Southern California Aviation  
Council, Inc.  
c/o World Air Show  
P.O. Box 1976  
Pasadena, Ca. 91109  
(213) 795-8150

John B. Nichols  
President  
United Technical Industries  
132 3rd St  
Manhattan Beach, Ca. 90266  
(213) 372-0816

R

Jack N. Nielsen  
President  
Nielsen Engineering & Research, Inc.  
510 Clyde Ave.  
Mountain View, Ca. 94043  
(415) 968-9457

Hans W. Nykamp  
Asst. Manager  
German National Tourist Office  
323 Geary St.  
San Francisco, Ca. 94102  
(415) 986-0796

Michael F. Odell  
Engineering Technician  
Naval Postgraduate School  
Code 57  
Monterey, Ca. 93940  
(408) 646-2997

George J. O'Hara  
Consultant  
Naval Research Laboratory  
Code 8403  
Washington, D.C. 20375  
(202) 767-3158

Richard G. O'Lone  
Bureau Chief, Aviation Week &  
Space Technology  
McGraw-Hill Publications Co.  
425 Battery St.  
San Francisco, Ca. 94111  
(415) 362-4600

E. T. Olsen  
Attorney  
Schiff, Hardin & Waite  
7200 Sears Tower  
233 S. Wacker Dr.  
Chicago, Il. 60606  
(312) 876-1000

George Papst  
Engineer  
Papst-Motoren K.G.  
D-7742 St. Georgen im Schwarzwald  
West Germany  
07724-811

Hermann Papst  
President  
Papst-Motoren K.G.  
D-7742 St. Georgen im Schwarzwald  
West Germany  
07724-811

Ralph Paskman  
Producer, CBS News/60 Minutes  
CBS, Inc.  
524 W. 57th St.  
New York, N.Y. 10019  
(212) 765-4321, ext. 3003

Ashton M. Patterson  
Deputy Chief, Defense Research  
Canadian Defense Liaison Staff  
2450 Massachusetts Ave., N.W.  
Washington, D.C. 20008  
(202) 483-5505, ext. 301

Robert L. Paullin  
Chief, R&D Policy Implementation  
Division  
Office of R&D Policy  
Dept. of Transportation  
TST-13  
400 7th St., S.W.  
Washington, D.C. 20590  
(202) 426-9547

V. Pavlecka  
Technical Task Force on Lighter  
Than Air  
Southern California Aviation  
Council, Inc.  
c/o World Air Show  
P.O. Box 1976  
Pasadena, Ca. 91109  
(213) 795-8150

Russel G. Perkins, Jr.  
Aircraft Concepts Manager  
Naval Air Systems Command  
AIR-03P32  
Washington, D.C. 20361  
(202) 692-7393, 4



Richard H. Petersen  
Senior Research Engineer  
Nielsen Engineering & Research, Inc.  
510 Clyde Ave.  
Mountain View, Ca. 94043  
(415) 968-9457

Frank N. Piasecki  
President  
Piasecki Aircraft Corp.  
Island Road  
International Airport  
Philadelphia, Pa. 19153  
(215) 365-2222

S. Joseph Pipitone  
Asst. to the Chief Engineer  
Goodyear Aerospace  
Dept. 915G  
1210 Massillon Rd.  
Akron, Oh. 44315  
(216) 836-4450

Russell A. Pohl  
Vice President  
Raven Industries, Inc.  
P.O. Box 1007  
Sioux Falls, S.D. 57101  
(605) 336-2750

Howard L. Power, Jr.  
Asst. Professor, Aeronautics  
Naval Postgraduate School  
Code 57  
Monterey, Ca. 93940  
(408) 646-2847

Kenneth J. Powers  
Systems Analyst  
Naval Electronics Laboratory Center  
Code 232  
San Diego, Ca. 92152  
(714) 225-6571

George Rappaport  
Technical Representative  
ILC Dover  
350 Pear St  
Dover, De. 19901  
(402) 674 4020, ext. 335

Harold E. Reed  
Project Engineer, Range  
Measurements Laboratory  
MU 716  
Patrick Air Force Base, Fl. 32925  
(305) 494-2681

Frank J. Regan  
Supervisory Aerospace Engineer  
Naval Ordnance Laboratory  
Bldg. 402-201  
Silver Spring, Md. 20910  
(301) 394-2056

Ronald D. Resch  
Assoc. Research Professor,  
Computer Science  
University of Utah  
Salt Lake City, Ut. 84112  
(801) 581-8224/6139

C. B. Rice (Mrs. E. T.)  
Physicist  
Physics Research Division  
24 Belair Rd.  
Wellesley, Ma. 02181  
(617) 861-3104

L. P. Richards  
Director  
Airfloat Transportation, Ltd.  
10 Glynswood  
Portsmouth Rd  
Camberley, Surrey  
England  
01-759-5511, ext. 21901

Paul O. Roberts  
Professor and Director, Center for  
Transportation Studies  
Massachusetts Institute of  
Technology  
Room 5 204  
Cambridge, Ma. 02139  
and 781-253-7123

John Roda  
Technical Task Force on Lighter  
Than Air  
Southern California Aviation  
Council, Inc.  
c/o World Air Show  
P.O. Box 1976  
Pasadena, Ca. 91109  
(213) 795-8150

Charles E. Rosendahl  
VAdm., USN (Ret.)  
Flag Point  
Toms River, N.J. 08753  
(201) 244-1102

Robert S. Ross  
Environmental Structures, Inc.  
7600 Wall St.  
Cleveland, Oh. 44125  
(216) 524-9270

Harry L. Runyan  
Asst. Chief, Structures & Dynamics  
Directorate  
NASA Langley Research Center  
MS-188  
Hampton, Va. 23665  
(804) 827-3121

Ralph L. Santi  
Lt. Cdr., USN  
Systems Analysis Tech. Officer  
Naval Undersea Center  
Code 154  
San Diego, Ca. 92132  
(714) 225-7595

J. F. M. Schatt  
Dipl.-Ing.  
Leiter der Zentralabteilung  
Luftfahrttechnik und der  
Flugbereitschaft  
Oberpfaffenhofen  
Deutsche Forschungs-und  
Versuchsanstalt für Luft-und  
Raumfahrt e. V.  
D-8031 Oberpfaffenhofen  
Post Wessling  
West Germany  
08153/28882

John J. Schneider  
Manager, Preliminary Design  
Boeing-Vertol Co.  
P.O. Box 16858  
Philadelphia, Pa. 19142  
(215) 522-3201

Ralph Schneider  
President  
Canadian Airship Developments  
55 Glenconneron Rd.  
No. 21 Thornhill  
Ontario 63T 1P2  
Canada  
(416) 881-0737

Melvin H. Scott, Jr.  
Mechanical Engineer  
Naval Weapons Center  
Code 4008  
China Lake, Ca. 93555

C. J. Seiberlich  
RAdm., USN  
Director, Naval Aviation Programs  
Division  
Dept. of the Navy  
OP 51  
Washington, D.C. 20330  
(202) 697-5507

James J. Sejd  
R&D Program Manager, Naval Sea  
System Command  
Dept. of the Navy  
Code 03222  
Washington, D.C. 20362  
(202) 692-8540

Howard Sharpe  
4925 Dufferin St.  
Downsview, Ontario  
Canada M3H 5T6

Duncan Sheldon  
President  
Transportation Technology, Inc.  
37 Pleasant St.  
Marblehead, Ma. 01945  
(617) 631-0793

R. L. Shelver  
Cdr. and Naval Attache  
Embassy of South Africa  
3051 Massachusetts Ave., N.W.  
Washington, D.C. 20008  
(202) 232-4400

Robert W. Simpson  
Professor and Director, Flight  
Transportation Laboratory  
Massachusetts Institute of  
Technology  
Room 33-412  
Cambridge, Ma. 02139  
(617) 253-3756

James A. Sizemore  
Supervisor, Mechanical Engineering  
Naval Weapons Laboratory  
Dahlgren, Va. 22448  
(703) 663-8591

Cynthia L. Smith  
Aerospace Engineer  
NASA Ames Research Center  
MS-202-7  
Moffett Field, Ca. 94035  
(415) 965-5887

Eugene A. Smith  
Senior Engineer  
Northrop Research & Technology  
Center  
3401 W. Broadway  
Hawthorne, Ca. 90250  
(213) 675-4611, ext. 4881

Miles Sonstegaard  
Assoc. Professor, Economics  
College of Business Administration  
University of Arkansas  
BA 235C  
Fayetteville, Ak. 72701  
(501) 575-2855

Clinton L. Spindler  
Head, Concept Analysis Branch  
Naval Weapons Center  
Code 4512  
China Lake, Ca. 93555  
(714) 939-7240

Kurt R. Stehling  
Science & Technology Advisor, NOAA  
Dept. of Commerce  
MR 6  
Rockville, Md. 20852  
(301) 496-6907

Robert E. Stevenson  
Oceanographer, Office of Naval  
Research  
Scripps Institute of Oceanography  
La Jolla, Ca. 92037  
(714) 453-2000, ext. 1276

Albert M. Stone  
Director, Advanced Research  
Projects  
Applied Physics Laboratory  
The Johns Hopkins University  
6621 Georgia Ave.  
Silver Spring, Md. 20910  
(301) 953-7100, ext. 3037

Richard S. Stone  
Sensor Research  
Arthur D. Little, Inc.  
15 Acorn Park  
Cambridge, Ma. 02140  
(617) 864-5770, ext. 2956

D. L. G. Sturgeon  
Research Supervisor, Textile Fibers  
Dept.  
duPont Experimental Station  
E. I. duPont de Nemours & Co., Inc.  
Bldg. 262  
Wilmington, De. 19898  
(302) 772-3376

James G. Sutton  
Senior Sales Engineer  
Hamilton Standard  
Windsor Locks, Ct. 06096  
(203) 623-1621, ext. 8933

Edwin S. Tankins  
Supervisory Metallurgist  
Naval Air Development Center  
Warminster, Pa. 18974  
(215) 672-9000, ext. 2808/9

Robert M. Taylor  
Aerospace Engineer, Advanced  
Concepts Office  
Naval Ship Research & Development  
Center  
Code 117  
Bethesda, Md. 20084  
(202) 227-1710

Henry Thornton  
Broker  
Allied Brokers  
P.O. Box 2253  
Dublin, Ca. 94566  
(415) 829-1212

Curtis E. Tucker, Jr.  
President and Director of  
Engineering  
Tucker Airship Co.  
13218 Lake St.  
Los Angeles, Ca. 90066  
(213) 398-6907

C. N. Tuomela  
Capt., USN  
Director, Aviation Safety Program  
Naval Postgraduate School  
Monterey, Ca. 93940  
(408) 645-2581 / 2/3

Keppie J. Turner  
Manager, Special Products  
Otis Engineering Corp.  
P.O. Box 34380  
Dallas, Tx. 75234  
(214) 242-8668, ext. 218

J. Gordon Vaeth  
Director, Systems Engineering  
National Environmental Satellite  
Service  
NOAA  
Washington, D.C. 20233  
(301) 763-5166/2724

A. B. van Time  
President  
Arctic Helifloat, Ltd.  
2104 Tenth Ave., N.W.  
Calgary, Alberta  
Canada T2N-1G5  
(403) 289-6951

John C. Vaughan  
Operations Research Analyst  
Naval Air Systems Command  
AIR-03P3  
Washington, D.C. 20361  
(202) 692-7392

Genevieve Vinas-Espin  
Chef de Service  
Aerospatiale  
12 Rue Beranger  
92320 Chatillon-sous-Bagneux  
France  
655-54-00, ext. 2319

Dorian L. Vittek  
LTA Workshop Manager  
Massachusetts Institute of  
Technology  
92 Mill St.  
Newton Centre, Ma. 02159  
(617) 969-1920

Joseph F. Vittek, Jr.  
LTA Workshop Director  
Asst. Prof. and Assoc. Director,  
Flight Transportation Laboratory  
Massachusetts Institute of  
Technology  
Room 33-404  
Cambridge, Ma. 02139  
(617) 253-7572

Woldemar Voigt  
Operations Analyst  
Naval Ship Research & Development  
Center  
Code 117  
Bethesda, Md. 20084  
(202) 227-1680

Christoph von Braun  
Systems Analyst  
Dorsch Consult gmbH  
8 Munich  
Eisenheimer STR. 63  
West Germany

Charles D. Walker  
Manager  
Aerling  
2408 H Street  
Bedford, In. 47421  
(812) 279-5685

Hepburn Walker, Jr.  
Rte. 2, Box 4-B  
Vero Beach, Fl. 32960  
(305) 567-6328

S. R. Wallin  
Lt. Cdr., USN  
716 Yorkshire Dr.  
Virginia Beach, Va. 23452  
(804) 486-3868

Mark Waters  
Branch Chief, Aeronautical  
Missions Branch  
NASA Ames Research Center  
MS-202-7  
Moffett Field, Ca. 94035  
(415) 965-5886

George F. Watson  
Capt., USN (Ret.)  
Staff Member (Ret.), M.I.T. Lincoln  
Laboratory  
P.O. Box 1951  
Litchfield Park, Ar. 85340  
(602) 935-2181

A. W. Webster  
Asst. to the President  
Megafifter  
P.O. Drawer J  
Goleta, Ca. 93017  
(805) 964-8573/3773

Donald F. Werb  
Senior Aerospace Design Engineer,  
Air Vehicle Tech. Dept.  
Naval Air Development Center  
Code 305  
Warminster, Pa. 18974  
(215) 672-9000, ext. 2478

P. R. Wessel  
Research Physicist  
Naval Ordnance Laboratory  
Code 244  
Silver Spring, Md. 20910  
(202) 394-2259

Don West  
Reporter  
San Francisco Examiner  
P.O. Box 3100  
San Francisco, Ca. 94119  
(415) 781-2424

Augie Westman  
Aeronaut-in-Charge  
Loon Balloon  
P.O. Box 2001  
Petaluma, Ca. 94852  
(707) 795-1201

Gerald B. White  
18283 Douglas Rd.  
South Bend, In. 46637  
(219) 283-7974

Duane H. Williams  
Head, Advanced Technology Division  
Naval Weapons Center  
China Lake, Ca. 93555  
(714) 939-7208

J. C. Williams  
Director, Transportation Systems  
Development, Research Dept  
Canadian Pacific, Ltd.  
Windsor Station, Room 365  
Montreal, Quebec  
Canada  
(514) 861-6811

Louis J. Williams  
Aerospace Engineer  
NASA Ames Research Center  
MS-202-7  
Moffett Field, Ca. 94035  
(415) 965-5887

O. C. Winzen  
President  
Winzen Research, Inc.  
Fleming Field  
South St. Paul, Mn. 55075  
(612) 455-1275

R. G. Witherow  
Manager, Structures and Materials  
Engineering Group  
Sheldahl, Inc.  
North Highway Three  
Northfield, Mn. 55057  
(507) 645-5633

Thomas Wolfe  
Vice President  
Southern California Aviation  
Council, Inc.  
1195 Rancheros Rd.  
Pasadena, Ca. 91103  
(213) 681-6138

A. P. Wood  
Head, Flight Research Laboratory  
National Aeronautical Establishment  
Montreal Rd.  
Ottawa, Ontario  
Canada  
(613) 995-3071

John E. R. Wood  
Aerospace Developments  
19/21 Newbury St.  
London EC1  
England  
606-5981

Steve W. Woodcock  
Operations Analyst  
Stanford Research Institute  
333 Ravenswood Ave.  
Menlo Park, Ca. 94025  
(415) 326-6200

Donald E. Woodward  
Senior Engineering Specialist  
GTE Sylvania  
922 S. Patrick St.  
Alexandria, Va. 22314  
(202) 325-9540

Al Worden  
Lt. Col., USAF  
Chief, Systems Study Division  
NASA Ames Research Center  
MS-202-7  
Moffett Field, Ca. 94035  
(415) 965-5357

**END  
DATE  
FILMED**

MAR 8 1976